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June 15, 2018

VIA ELECTRONIC FILING

Ms. Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, S.W.
Washington, D.C. 20554

Re: ***Written Ex Parte Communication***

GN Docket No. 17-183, *Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz; and*

GN Docket No. 18-122, *Expanding Flexible Use of the 3.7 GHz to 4.2 GHz Band.*

Dear Ms. Dortch:

T-Mobile USA, Inc. ("T-Mobile")[1/] appreciates the Commission's continued efforts to make mid-band spectrum available for terrestrial wireless use. As the record in the above proceedings demonstrates, countries around the world are pursuing mid-band spectrum as a critical input for fifth generation wireless ("5G") networks.[2/] The 3.7-4.2 GHz band presents the Commission with an important opportunity to ensure that the U.S. remains at the forefront of 5G development. The band's propagation characteristics and available bandwidth make it ideal for next generation wireless services. T-Mobile therefore applauds Chairman Pai's announcement that he will introduce a Notice of Proposed Rulemaking ("NPRM") proposing more intensive, terrestrial use of the 3.7-4.2 GHz band at the Commission's July meeting.[3/]

As many have noted, in order to maximize the utility of the 3.7-4.2 GHz band for 5G wireless terrestrial use, the Commission must address the presence of satellite incumbents in the

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1/ T-Mobile USA, Inc. is a wholly owned subsidiary of T-Mobile US, Inc., a publicly traded company.

2/ *See, e.g.*, Comments of CTIA, GN Docket No. 18-122, at 3 (filed May 31, 2018) ("Across the globe, the race for 5G is on and mid-band spectrum is increasingly viewed as a key component to unlocking the benefits of 5G connectivity."); Comments of Nokia, GN Docket No. 17-183, at 5 (filed Oct. 2, 2017) ("The 3.55-4.2 GHz range is also being considered in other regions and countries for 5G and has a potential to become a globally harmonized range.").

3/ Remarks of FCC Chairman Ajit Pai at the Wireless Infrastructure Association Connectivity Expo, Charlotte, NC (May 23, 2018), https://docs.fcc.gov/public/attachments/DOC-350919A1.pdf.

spectrum. While commenters have explained that incumbent use of the band is both declining and overstated,[4/] the Commission has appropriately taken steps to more accurately assess the current use of the band.[5/] Regardless of the level of satellite use of the band, in order to transition it to 5G wireless terrestrial service, the Commission must determine how incumbent operations can be accommodated by other media, and the mechanism for re-licensing the band for 5G terrestrial wireless operations.

This letter provides studies and information relevant to solutions for both issues. T-Mobile therefore requests that the Commission seek comment on the information and proposals presented in this filing in its anticipated NPRM.

Incumbents Can Vacate the 3.7-4.2 GHz Band Using Alternative Facilities

Current C-band satellite uses can be accommodated by alternative facilities, allowing the 3.7-4.2 GHz band to be cleared for terrestrial wireless use. In many cases, incumbent satellite earth station facilities can be relocated away from urban areas with backhauling accomplished by fiber, which is heavily deployed throughout the country.[6/]

As explained in the record, protection zones between satellite earth stations and terrestrial wireless services are necessary to avoid harmful interference. Ericsson, for example, has stated that protection zones between 30-40 kilometers are necessary for satellite and terrestrial co-channel sharing,[7/] and SES Americom explained that large separation distances of at least 30 kilometers would be necessary to protect C-band earth stations from terrestrial wireless

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4/ *See, e.g.*, CTIA Comments at 8-9 ("FSS rules designed to protect against interference are overprotective, contributing to the inefficient use of the band. This is due largely to the fact that earth station receive licensees in the band have access to much more spectrum than they use."); Comments of Google LLC and Alphabet Access, GN Docket No. 17-183, at 4 (filed Oct. 2, 2017) ("Our analysis of Google Earth imagery of 4,724 IBFS-registered C-band FSS sites indicates that at 1,371 of the sites there is no satellite dish within approximately 1 km of the listed coordinates. In other words, approximately 29% of these registered locations are clearly not being used for satellite services despite being registered in IBFS."); Comments of Verizon, GN Docket No. 18-122, at 1-2 (filed May 31, 2017) ("Currently, both the Fixed Satellite Service (FSS) and the terrestrial Fixed Service (FS) use the band, though neither—either on its own or collectively with the other—appears to fully use the band. At the time the Mid-Band Spectrum NOI was released, there were 4,700 registered FSS users, many of which appeared not to exist.").

5/ *See Temporary Freeze on Applications for New or Modified Fixed Satellite Service Earth Stations and Fixed Microwave Stations in the 3.7-4.2 GHz Band; 90-Day Window to File Applications for Earth Stations Currently Operating in the 3.7-4.2 GHz Band*, Public Notice, DA 18-398 (rel. Apr. 19, 2018).

6/ In fact, Comcast explained that it already uses a significant amount of fiber for its video distribution services. *See, e.g.*, Comcast Corporation, Notice of *Ex Parte*, GN Docket No. 17-183, GN Docket No. 18-122 (filed May 10, 2018); Comcast Corporation, Notice of *Ex Parte*, GN Docket No. 17-183, GN Docket No. 18-122 (filed May 16, 2018).

7/ *See* Comments of Ericsson, GN Docket No. 17-183, at Attachment A (filed Oct. 2, 2017); Comments of Ericsson, GN Docket Nos. 17-193, 18-122, at 5 (filed May 31, 2018).

operations.[8/] The higher the population within the protection zones, the greater the potential impact on mobile use of the spectrum. Accordingly, relocating earth stations outside of urban areas will reduce the likelihood of interference to mobile services and *vice versa*. Traffic from the new earth station location could then be backhauled to the original site.

Such relocation to alternative facilities is readily achievable. The attached case study demonstrates the feasibility of clearing all earth station use within 60 kilometers of the Phoenix Cellular Market Area ("CMA").[9/] The Phoenix Study includes a map and list of the relocated stations. The Phoenix Study considered two primary options. The first option examines a case in which a user has another receive earth station located farther outside of Phoenix, and backhauls traffic from the farther station via fiber to the current nearer station.[10/] Earth stations operated by the Associated Press, Cable One, Cox, and Fox fall under this option. The second case examines a situation in which a user does not have access to alternative facilities, so an antenna farm is created outside the Phoenix metropolitan area with traffic then backhauled to the current earth station location.[11/] All other earth stations studied fall under this option. Maps demonstrating these two options are included in the study. The Phoenix Study shows the earth stations that would be affected by reallocating the 3.7-4.2 GHz band for 5G wireless terrestrial use and demonstrates how traffic currently received at those earth stations could be re-configured. This approach would fully accommodate end user requirements while permitting the 3.7-4.2 GHz band to be used to meet critical 5G wireless terrestrial mid-band spectrum needs.

Roberson and Associates, LLC conducted a similar analysis, examining how traffic received by earth stations in Chicago can be accommodated in a reallocation of the 3.7-4.2 GHz band.[12/] A copy of this study is also attached. The Roberson Study assumes the same goal as the Phoenix Study – clearing all satellite receivers from C-band downlink spectrum in an urban area. The Roberson Study, however, suggests that there may be additional alternatives to continuing to receive content via backhauled satellite transmissions. The primary option – as in the Phoenix Study – would be the relocation of current satellite earth stations to areas outside the urban core. An alternative the Roberson Study considers is receipt of content exclusively via fiber links, rather than through earth station locations. As the Roberson Study demonstrates, there are multiple fiber providers, including Internet Service Providers ("ISPs"), in the Chicago area.[13/] And over half of the ISPs mentioned in the study have more than 80% coverage in Chicago.[14/]

In addition to presenting options for accommodating traffic received by current C-band earth stations, the Roberson Study examined the cost models for each of the proposed options.

8/ *See* Reply Comments of SES Americom, GN Docket No. 17-183, at 18-20 (filed Nov. 15, 2017).

9/ THE PHOENIX STUDY (2018).

10/ *Id.* at 5-9.

11/ *Id.* at 5, 10.

12/ ROBERSON AND ASSOCIATES, LLC, MID-BAND ASSESSMENT: COST FACTORS AFFECTING FIBER AS AN ALTERNATIVE TO SATELLITE (2018).

13/ *Id.* at 19, 23.

14/ *Id.* at 23.

According to the estimates, implementing the two options in the Chicago area would cost approximately $8 million – a minimal amount in comparison to the value of spectrum in Chicago.[15/]

The Commission Should Auction the 3.7-4.2 GHz Band

As the analyses discussed above demonstrate, it is possible to clear a significant portion of the 3.7-4.2 GHz spectrum while still meeting the operational requirements of the band's incumbents. The Commission should therefore maximize the opportunity for 5G wireless terrestrial mid-band spectrum use by making *all* of the spectrum in the 3.7-4.2 GHz band available in an auction and using the techniques noted above and the market-based auction mechanisms described here to address incumbent operations.

As T-Mobile has recognized in the past, the presence of incumbent operations means that the Commission may wish to consider auction processes that incorporate market forces that can help expedite incumbent relocation processes.[16/] The SES, Intel, and Intelsat proposal,[17/] which would use market-based approaches to incentivize relocation, is a step in the right direction. But as T-Mobile previously detailed,[18/] the proposal has several flaws. Most notably, there is no guarantee that any spectrum would actually be made available for wireless use. And where spectrum is made available, the sellers would have a monopoly they could use to demand prices that a truly competitive market would not support, which would make less than the socially optimal amount of spectrum available for terrestrial use. The Commission should therefore not adopt the SES, Intel, and Intelsat proposal as it has been presented. Any licensing and relocation mechanism the Commission adopts should promote the greatest possible amount of terrestrial

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15/ *See, e.g., The Incentive Auction "By the Numbers,"* FCC, https://docs.fcc.gov/public/attachments/DOC-344398A1.pdf (stating that the average price/MHz-pop sold in the Top 40 PEAs in the broadcast incentive auction was $1.31); Phil Goldstein, *Analysts: Bidding in NYC, LA and Chicago in AWS-3 Auction Is 94% Above Average Prices*, FIERCEWIRELESS (Dec. 19, 2014, 11:47 AM), https://www.fiercewireless.com/wireless/analysts-bidding-nyc-la-and-chicago-aws-3-auction-94-above-average-prices (discussing the AWS-3 auction and estimates that "'the three largest U.S. cities are going for a price of $4.29 per MHz/POP (including paired and unpaired)--or 94% above the average price.'").

16/ *See* Reply Comments of T-Mobile USA, Inc., GN Docket No. 17-183, at 16 (filed Nov. 15, 2017) ("[A] licensee with sufficient incentive may be able to clear spectrum and find alternative means for meeting service requirements more quickly and efficiently than an incumbent forced to clear pursuant to a mandate.").

17/ Intelsat, Intel, and SES propose a consortium of satellite operators that would clear "a target" of approximately 100 megahertz of spectrum and that would negotiate secondary market agreements with terrestrial mobile service providers for access to specific spectrum blocks on a market-by-market basis. Terrestrial providers would then apply to the Commission for licenses authorizing them to provide service in the agreed-upon market areas and spectrum blocks. *See* SES Americom, Inc. and Intelsat Corporation, Notice of *Ex Parte*, GN Docket No. 17-183 (filed Feb. 9, 2018).

18/ *See, e.g.*, T-Mobile USA, Inc. Notice of *Ex Parte*, GN Docket Nos. 17-183, 17-258, and 14-177, at 4 (filed Feb. 14, 2018); Reply Comments of T-Mobile USA, Inc., GN Docket No. 17-183, at 13-14 (filed Nov. 15, 2017).

mobile use and eliminate the potential for monopoly pricing or actions by a single licensee to block access to the band.

T-Mobile therefore proposes an outline of an alternative method for conducting an auction of the 3.7-4.2 GHz band for 5G wireless terrestrial use. T-Mobile's proposal is intended to promote the availability of spectrum in all geographic areas and would allow satellite operators to participate in an auction process to determine the value of the spectrum for satellite service relative to terrestrial mobile service. The proposal presented here is not intended to provide all the relevant details regarding how the auction would be conducted – T-Mobile expects that responses to the NPRM will provide the Commission with feedback on the additional auction components, some of which are identified below.

The proposal's core framework is an incentive auction with a descending amount of spectrum, in which a consortium comprised of all satellite licensees (the "satellite consortium") is the seller and potential wireless providers would be the buyers.[19/] Broadly, the proposed framework would proceed as follows:

1. *Phase 1 – Initial Price Setting for all 500 Megahertz.* The first phase of the T-Mobile plan would be an auction for licenses for all 500 megahertz of spectrum in each geographic area. Consistent with the geographic area in the 600 MHz incentive auction and in other upcoming auctions,[20/] T-Mobile proposes that the Commission auction the 3.7-4.2 GHz band on a Partial Economic Area ("PEA") basis (the amount of spectrum in each block available at auction would be determined based on comments received in response to the NPRM). The auction would also include – in addition to the standard geographic area licenses – a limited number of license areas defined by the satellite consortium and within which satellite operations could be protected from terrestrial wireless operations. These satellite designated zones ("SDZs") would be carved out from and auctioned alongside the PEA license areas as described below. The means by which SDZs are defined and the number permitted per PEA would be developed through the NPRM responses. But, their location and number would be intended to accommodate satellite use as described in the Phoenix Study and the Roberson Study and would be structured to impose a limited impact on 5G wireless terrestrial use in the PEA.
2. *Phase 2 – Satellite Consortium Opportunity to Sell all 500 Megahertz at Initial Price.* The second phase of the T-Mobile plan would permit the satellite consortium to sell the 500 megahertz of spectrum at the prices per area established in the initial phase. The satellite consortium would be treated as a single reverse auction seller that would identify the geographic areas in which its members would vacate all 500 megahertz for the initial auction phase price. These areas would be deemed "cleared" for terrestrial wireless use.

19/ One of the issues the Commission would be required to address is the potential of satellite providers *not* participating in the consortium.

20/ *See Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report and Order, 29 FCC Rcd 6567, ¶ 44 (2014); *Auctions of Upper Microwave Flexible Use Licenses for Next-Generation Wireless Services; Comment Sought on Competitive Bidding Procedures for Auctions 101 (28 GHz) and 102 (24 GHz); Bidding in Auction 101 Scheduled to Begin November 14, 2018*, Public Notice, FCC 18-43, ¶ 3 (rel. Apr. 17, 2018) ("Auction 102 will offer 2,912 licenses in the 24 GHz band, and the licenses will be based on PEAs.").

All geographic areas for which 500 megahertz is not cleared would be included in the next phase of the auction.

3. *Phases 3, 4 and Beyond —Price Setting for Decreasing Amounts of Spectrum in Uncleared Areas Followed by Reverse Auctions for Those Areas.* During the third phase, another forward auction would be held for the remaining, uncleared geographic areas, but now with some pre-designated amount of spectrum held out of the auction and reserved for satellite use. As before, a reverse auction would follow in which the satellite consortium would choose the areas in which its members would vacate the amount of broadband spectrum to be cleared for the forward auction price. This process would repeat, each time reducing the amount of spectrum available for wireless use in each license area where the satellite consortium had not accepted the forward auction price, until a Commission-determined minimum amount of spectrum per geographic area is reached.[21/]
4. *Minimum Spectrum Phase.* The final phase would be a forward auction only. Satellite companies would be required to vacate a Commission-designated minimum amount of spectrum in all remaining areas, regardless of the price received.
5. *Assignment Round.* After the phases above, there would be an assignment round similar to that in the 600 MHz incentive auction. Any spectrum that is not won at auction would remain authorized for satellite use.

Auction revenues would be split between the federal government and the satellite consortium.[22/] In exchange for those revenues, the satellite consortium would be responsible for the costs, if any, of relocating end users. To incentivize the satellite consortium to clear the greatest amount of spectrum, T-Mobile proposes dividing the revenues on a sliding scale: the more spectrum cleared in a geographic area, the higher the percentage of revenues the satellite consortium receives in that area. For instance, if all 500 megahertz is cleared the satellite incumbents might receive 100% of the auction revenue; if 400 megahertz is cleared they might receive 80%, etc. Apportioning the revenues on a sliding scale would counterbalance the monopoly incentives of the satellite consortium and provide it with an economic incentive to sell spectrum while granting the satellite consortium the opportunity to retain the spectrum its members deem necessary for continued service.

While the above describes a core framework for a 3.7-4.2 GHz band auction, as noted, further development is necessary. The Commission should therefore seek comment on this auction proposal and on ways to refine it in the upcoming NPRM. T-Mobile has identified several of the open issues above, including:

21/ The Commission may wish to consider whether the amount of spectrum that can be retained by the satellite consortium may be different in SDZs than in PEAs. Notably, satellite industry representatives have stated that they would be able to make a minimum of 100 megahertz available wireless use. *See, e.g.*, SES Americom and Intelsat, Notice of *Ex Parte*, GN Docket Nos. 17-183, 18-122, at 2 (filed May 23, 2018).

22/ In the NPRM, the Commission would be required to explore the contours of its authority to distribute proceeds of the auction to the satellite consortium.

- the amount of spectrum in each block that will be available at auction;
- how SDZs are defined and the number of SDZs per PEA permitted;
- the minimum amount of spectrum satellite companies will be required to vacate in each license area;
- how to address the potential of satellite providers declining to participate in the satellite consortium; and
- the contours of the Commission's authority to distribute proceeds of the auction to the satellite consortium.

Conclusion

Clearing the 3.7-4.2 GHz band by relocating satellite incumbents and auctioning the 500 megahertz of spectrum for 5G wireless terrestrial use will help ensure that the U.S. remains in step with other countries in the global race to 5G. T-Mobile therefore urges the Commission to seek comment on the proposals presented in this letter and on the attached analyses regarding relocation of satellite incumbents from the 3.7-4.2 GHz band in its upcoming NPRM.

* * *

Pursuant to Section 1.1206(b)(2) of the Commission's rules, an electronic copy of this letter is being filed in the above-referenced dockets. Please direct any questions regarding this filing to me.

Respectfully submitted,

/s/ Steve B. Sharkey

Steve B. Sharkey
Vice President, Government Affairs
Technology and Engineering Policy

Attachments

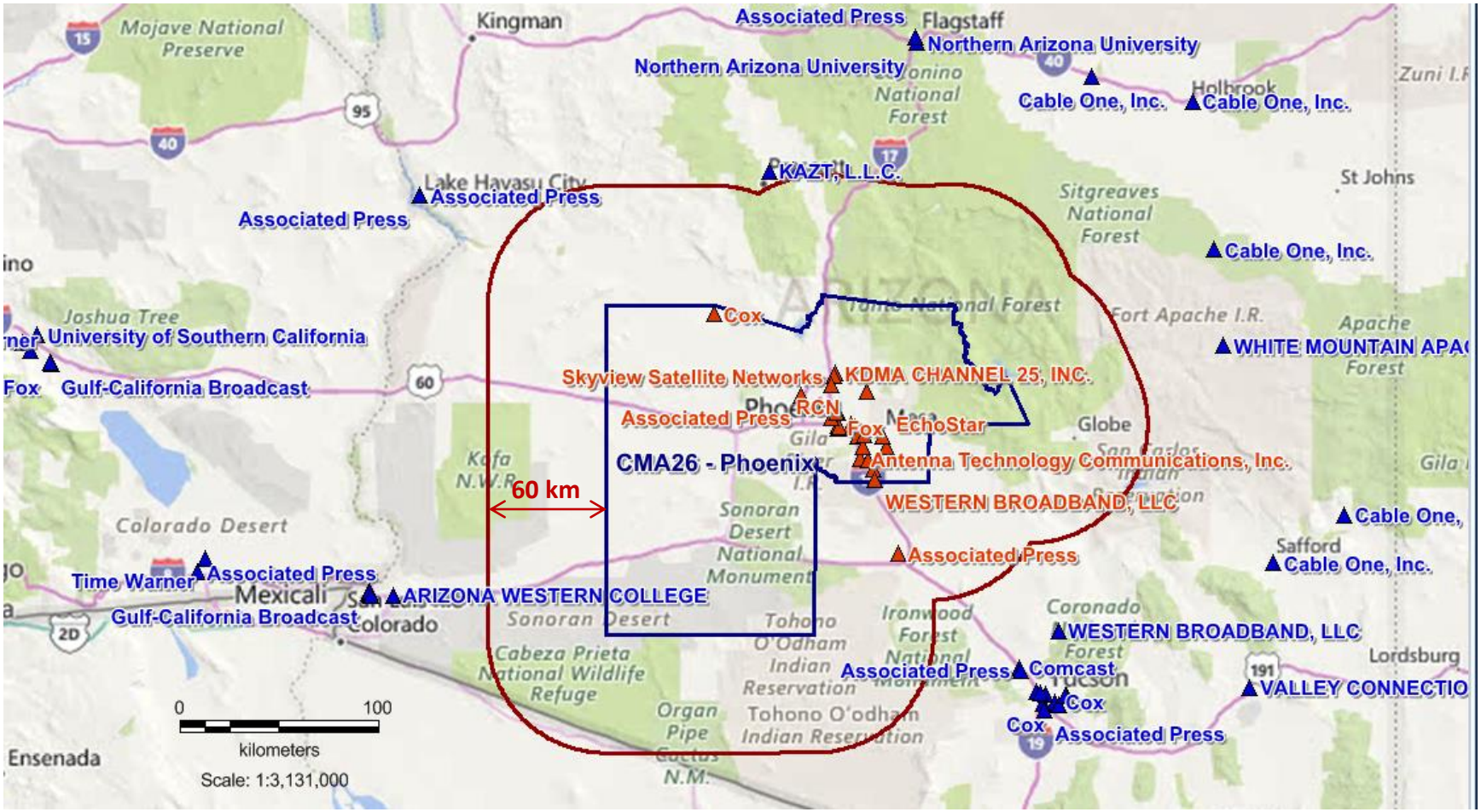
Phoenix Earth Station Relocation Study

May 30, 2018

Phoenix Case Study

- There are studies in the record that demonstrate the separation distance required between IMT base stations and C band earth stations to prevent interference to earth stations
  - Ericsson filed a study on October 2, 2017 that concluded a minimum separation distance of 30 kilometers would be required, and as high as 50 – 70 kilometers for more stringent I/N assumption and lower earth station elevation angles
  - SES filed a study on March 2, 2018 which confirmed Ericsson's results by showing that the distance required to protect five earth stations from a single base station in the Virginia Beach area was 30-40 kilometers
- Both studies considered earth stations in urban and suburban areas
- Neither study considered additional commonly-applied mitigation techniques such as shielding that could reduce the separation distance required
- Neither study contemplated moving urban and suburban base stations to rural areas
- To understand the feasibility of relocating C band earth stations and the requirements for doing so, the following study contemplates relocating all earth stations within 60 kilometers of the Phoenix CMA border to more remote locations outside the CMA
  - This would free up the entire 500 MHz of the C band for wireless broadband use in the entire CMA
  - This is an overly conservative approach that may be modified for other markets

Phoenix C Band Earth Stations



Relocation of 33 licensed earth stations within 60 kilometers of the Phoenix CMA (orange triangles) frees up 500 MHz of spectrum in the CMA

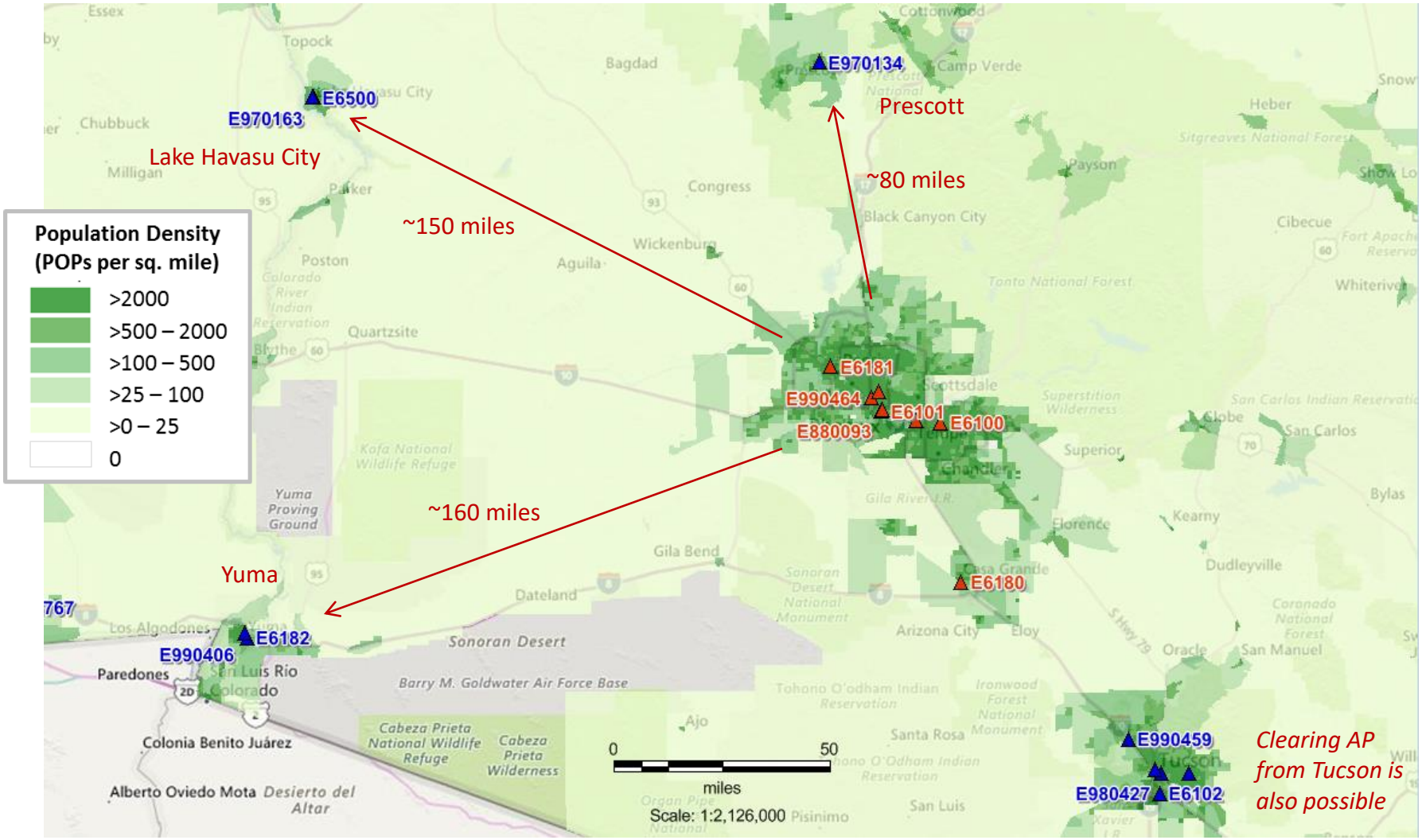
Phoenix C Band Earth Stations

Call_Sign	Licensee	Case	File_Num	Location	State	AMSL	Lat	Lon
E6100	Associated Press	1	SES-RWL-20030826-01180	MESA	AZ	376.4	33.4133	-111.8342
E6101	Associated Press	1	SES-RWL-20030826-01167	PHOENIX	AZ	332.1	33.4517	-112.0711
E6180	Associated Press	1	SES-RWL-20030916-01289	CASA GRANDE	AZ	425.2	32.8772	-111.7525
E6181	Associated Press	1	SES-RWL-20030916-01290	SUN CITY	AZ	349.6	33.6003	-112.2756
E880093	Associated Press	1	SES-RWL-20071127-01619	PHOENIX	AZ	331	33.4539	-112.0697
E980439	Associated Press	1	SES-RWL-20080903-01144	Tempe	AZ	355.1	33.4197	-111.9335
E990464	Associated Press	1	SES-RWL-20091029-01373	PHOENIX	AZ	339.2	33.4944	-112.1133
E990490	Associated Press	1	SES-RWL-20091029-01393	PHOENIX	AZ	348.7	33.5178	-112.0825
E040294	Cable One, Inc.	1	SES-LIC-20040702-00951	CHANDLER	AZ	352	33.3111	-111.9540
E3991	Cox	1	SES-RWL-20120112-00053	WICKENBURG	AZ	677	33.9650	-112.7525
E8014	Cox	1	SES-RWL-20041215-01841	PHOENIX	AZ	410	33.6456	-112.1156
E970204	Cox	1	SES-RWL-20070207-00200	CHANDLER	AZ	359.7	33.3042	-111.9128
E000528	Fox	1	SES-RWL-20100717-00930	PHOENIX	AZ	329.18	33.4486	-112.0804
E000529	Fox	1	SES-RWL-20100717-00931	PHOENIX	AZ	347.47	33.5180	-112.0799
E010254	Antenna Technology Communications, Inc.	2	SES-MOD-20140304-00124	CHANDLER	AZ	352	33.3111	-111.9533
E010255	Antenna Technology Communications, Inc.	2	SES-MOD-20140304-00123	CHANDLER	AZ	352	33.3111	-111.9533
E140033	Antenna Technology Communications, Inc.	2	SES-LIC-20140304-00122	Chandler	AZ	357.2	33.3111	-111.9532
E130055	CBS	2	SES-REG-20130318-00271	Phoenix	AZ	331.01	33.4579	-112.0744
E020233	EchoStar	2	SES-RWL-20170919-01033	GILBERT	AZ	381	33.3669	-111.8147
E060399	EchoStar	2	SES-LIC-20061031-01927	Gilbert	AZ	371.86	33.3668	-111.8137
E170093	EchoStar	2	SES-LIC-20170414-00403	Gilbert	AZ	381	33.3667	-111.8147
E970396	EchoStar	2	SES-RWL-20070921-01306	GILBERT	AZ	371.3	33.3668	-111.8142
E030162	Iridium Constellation LLC	2	SES-LIC-20030722-01016	Chandler	AZ	362.7	33.2663	-111.8815
E030112	KDMA CHANNEL 25, INC.	2	SES-REG-20030513-00643	PHOENIX	AZ	440.1	33.6955	-112.0947
E950195	KPHO Broadcasting Corporation	2	SES-MOD-20160104-00002	PHOENIX	AZ	348.9	33.5184	-112.0809
E060267	Maricopa County Community College District	2	SES-REG-20060717-01163	TEMPE	AZ	348.1	33.4124	-111.9737
E980342	Qwest Broadband Services, Inc.	2	SES-RWL-20080625-00845	TEMPE	AZ	364.2	33.3647	-111.9400
E040085	RCN	2	SES-LIC-20040213-00226	Phoenix	AZ	346.86	33.4461	-112.0000
E050221	Scripps	2	SES-REG-20050715-00927	PHOENIX	AZ	353.57	33.4545	-111.9846
E170123	Skyview Satellite Networks	2	SES-LIC-20170710-00745	Phoenix	AZ	438.91	33.6851	-112.0974
E170124	Skyview Satellite Networks	2	SES-LIC-20170710-00746	Scottsdale	AZ	441.96	33.6169	-111.9207
E130154	Trinity Broadcasting	2	SES-REG-20130813-00724	PHOENIX	AZ	350.65	33.4647	-112.0047
E6020	WESTERN BROADBAND, LLC	1 or 2	SES-RWL-20070305-00297	SUN LAKE	AZ	362.7	33.2181	-111.8769

Proposal

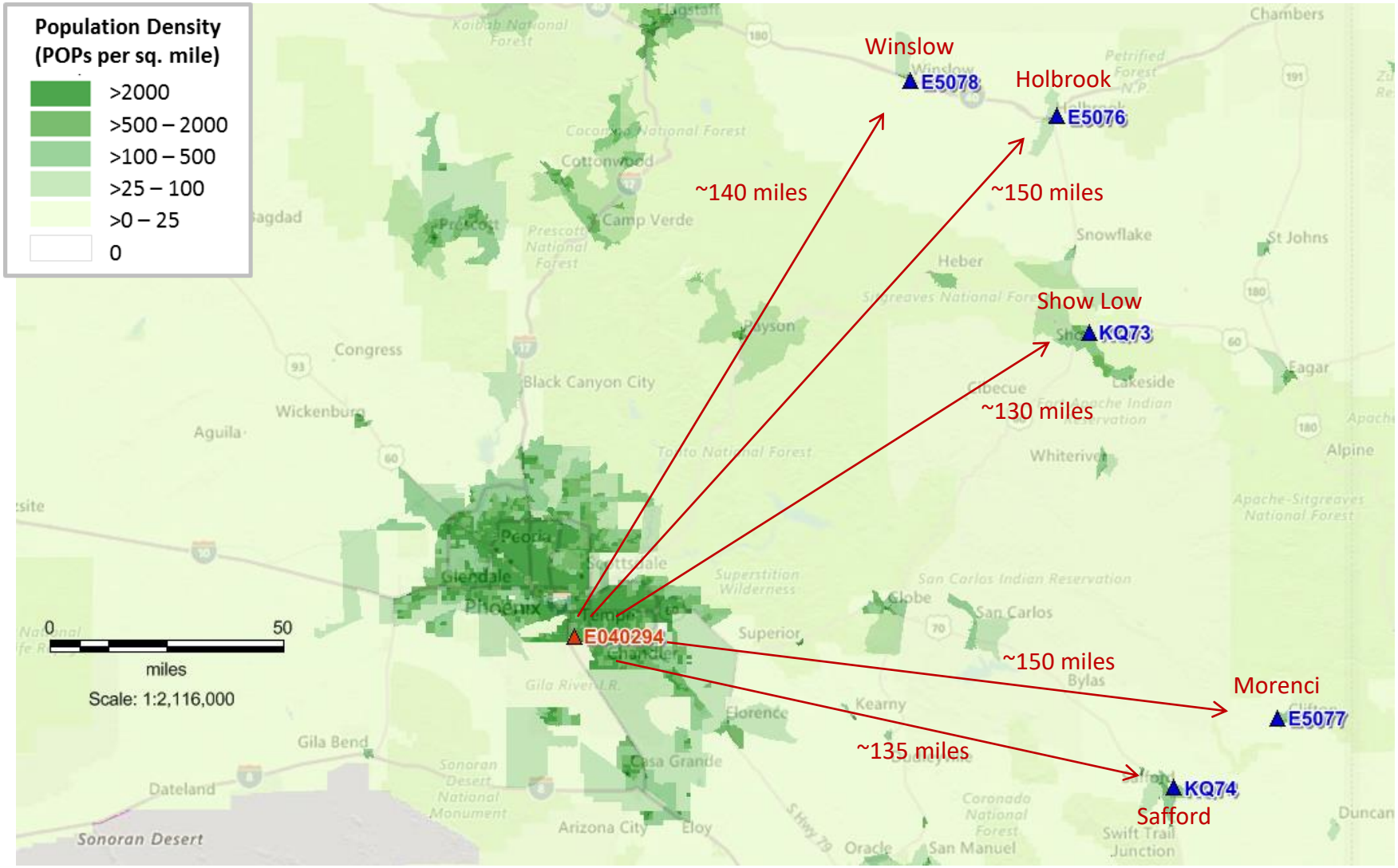
1. Some licensees operating earth stations that need to be relocated also operate earth stations outside the 60 kilometer buffer and in suitably remote areas
   - In these cases, we propose to decommission the licensee's earth station(s) within the buffer and replace the service with a fiber feed from one of the licensee's nearby, remote earth stations
2. Other licensees do not have this option
   - In these cases, we propose to build a C band antenna farm in a remote location and connect the licensees to their antenna(s) by fiber
   - The antenna farm could include mitigation techniques such as shielding to reduce the separation distance required

Case 1: Associated Press Earth Stations



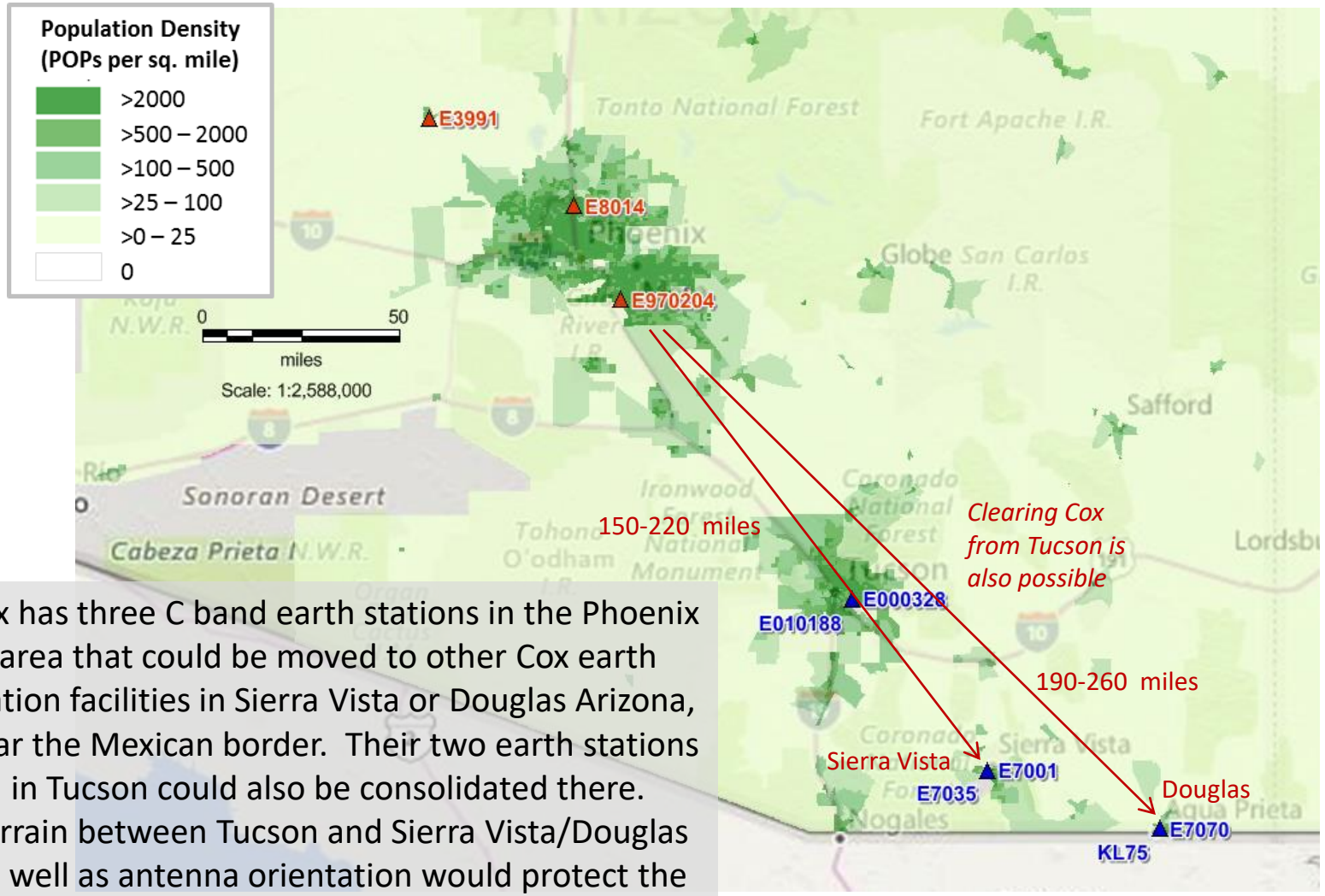
The satellite feeds to eight AP earth stations in Phoenix could be replaced by fiber feeds from existing satellite reception Yuma, Lake Havasu City, and/or Prescott, Arizona

Case 1: Cable One Earth Station



The satellite feeds to the Cable One earth station in Phoenix could be replaced by fiber feeds from existing Cable One earth stations in Winslow, Holbrook, Show Low, Morenci and/or Safford, Arizona

Case 1: Cox Earth Stations

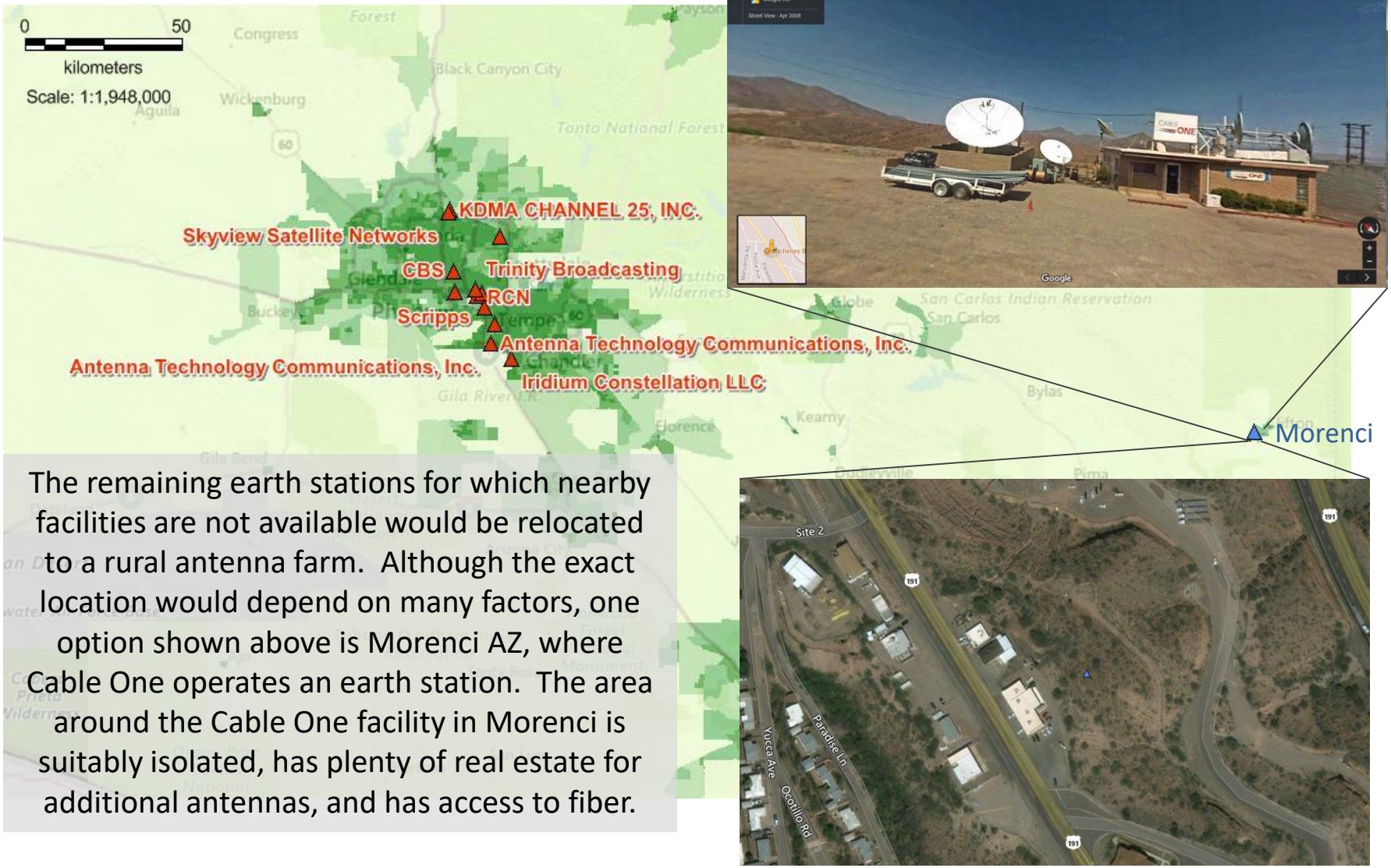


Cox has three C band earth stations in the Phoenix area that could be moved to other Cox earth station facilities in Sierra Vista or Douglas Arizona, near the Mexican border. Their two earth stations in Tucson could also be consolidated there. Terrain between Tucson and Sierra Vista/Douglas as well as antenna orientation would protect the earth stations from interference.

Case 1: Fox Earth Stations

Fox Broadcasting has two C band earth stations in the Phoenix area that could be decommissioned with services provided by Fox earth station facilities in Yuma Arizona.

Case 2: Rural Antenna Farm



The remaining earth stations for which nearby facilities are not available would be relocated to a rural antenna farm. Although the exact location would depend on many factors, one option shown above is Morenci AZ, where Cable One operates an earth station. The area around the Cable One facility in Morenci is suitably isolated, has plenty of real estate for additional antennas, and has access to fiber.

Mid-Band Assessment: Cost Factors Affecting Fiber as an Alternative to Satellite

Nat Natarajan
Mike Needham
Ed Porrett
Bill Payne
Dennis Roberson
Ken Zdunek

Roberson and Associates LLC
Schaumburg, Illinois 60173

14 June 2018

Roberson and Associates, LLC
Technology and Management Consultants ®

Summary of Analysis

- Replacement options for C-Band Satellite reception, in urban / metropolitan areas of US, with optional fiber based access links are identified

- Cost factors involved in the relocation of users are identified and evaluated for a major urban / suburban area (Chicago) in the US

- Conservative assumptions were used in modeling costs. These include:
  - Cost factors affecting fiber deployment
  - Availability of existing fiber links
  - Equipment replacement costs
  - Number of pre-existing and registered C-Band receivers (i.e. those registered as receive only stations in the IBFS database on or before July 18, 2018 FCC deadline) was assumed much larger than the Mid Band NOI estimate of 4,700 licensed or registered earth stations in the 3.7-4.2 GHz band

Results

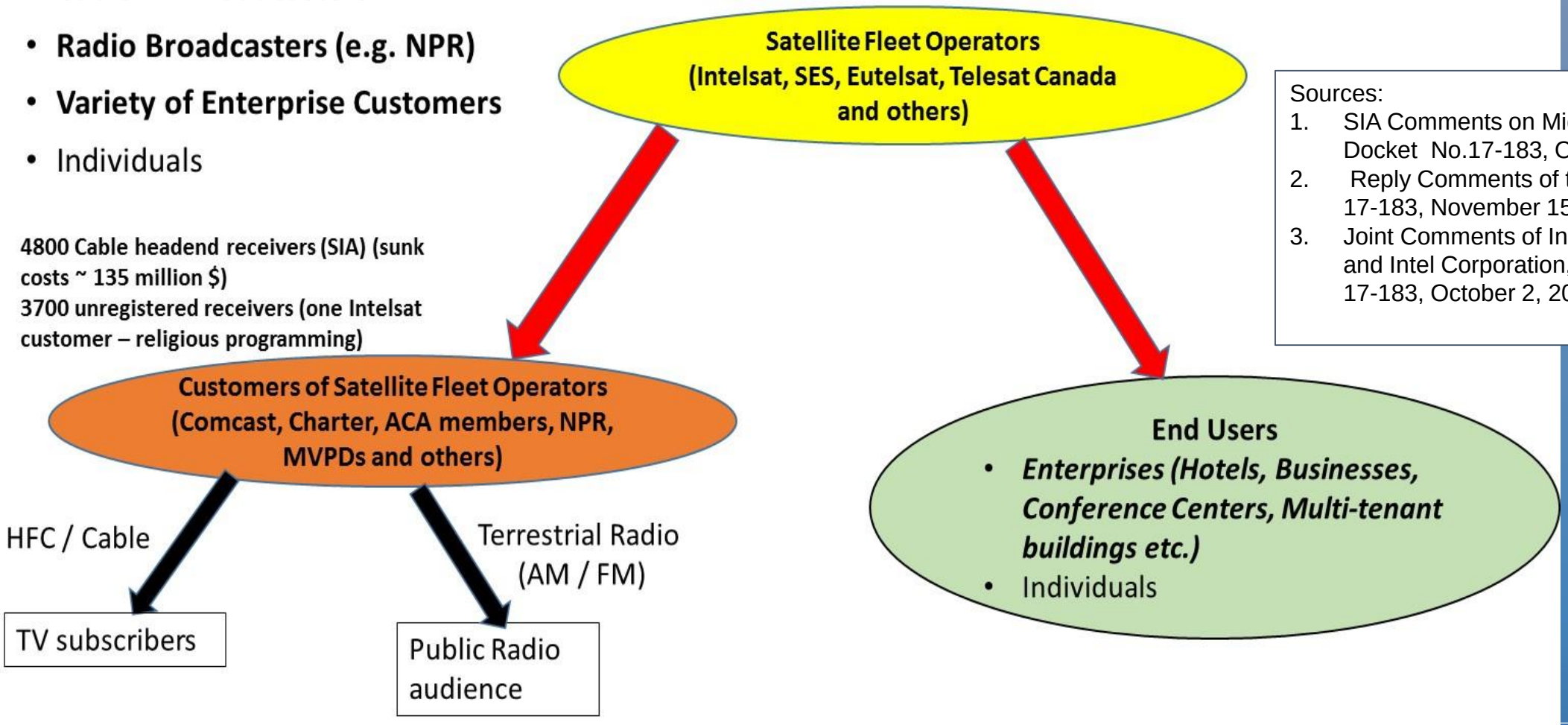
- Based on the modeling assumptions, a rough order of magnitude estimate for costs of relocating users in Chicago (urban/suburban areas) is developed
- Methodology can be applied to other metropolitan areas of the US
- Relocation methods do not impact the C-Band receivers operating in rural areas (MVPD operations serving smaller user communities) since they are not relocated and continue to receive satellite downlink transmissions
- Cost models could be refined with additional detailed input from stakeholders (satellite operators, cable operators and end users in specific markets)

Current Users of C-Band Downlink

Major Users

- **Cable TV Broadcasters**
- **Radio Broadcasters (e.g. NPR)**
- **Variety of Enterprise Customers**
- Individuals

- **4800 Cable headend receivers (SIA) (sunk costs ~ 135 million $)**
- **3700 unregistered receivers (one Intelsat customer – religious programming)**



Sources:

1. SIA Comments on Mid-Band NOI, Docket No.17-183, October 2, 2017
2. Reply Comments of the SIA, Docket No. 17-183, November 15, 2017
3. Joint Comments of Intelsat License LLC and Intel Corporation, GN Docket No. 17-183, October 2, 2017

C-Band Video Broadcast in US: By the Numbers

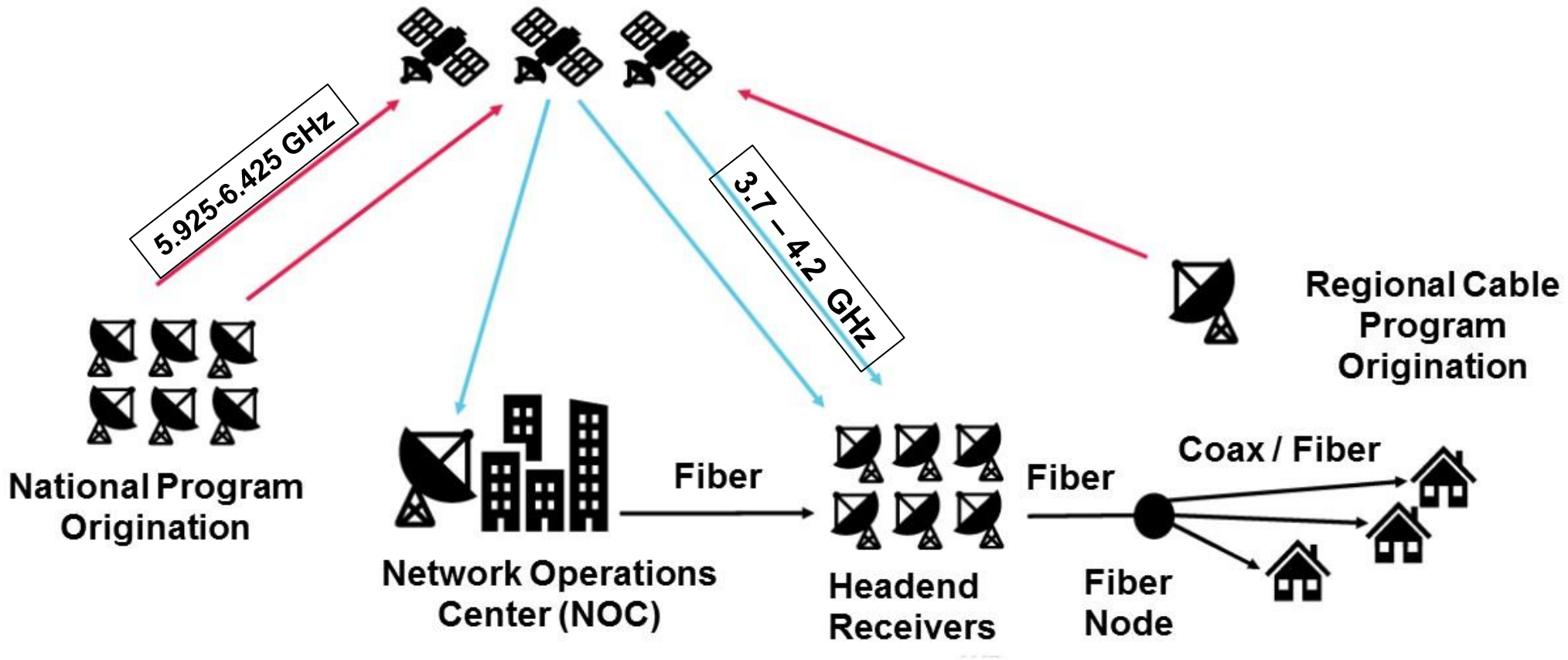
- Number of C-Band Satellites covering the US =24
- Total transponders = 308 (each using 36 MHz)
- Total feeds : 2012 (1781 video & 231 audio feeds)
- Video transmission at different resolutions: SD, HD & 4K
- MPEG encoding advances yield compression rates from 3:1 to 9:1 or higher
- Advanced modulation schemes deployed for spectral efficiency
- Each transponder can carry 20 SD channels or 8 HD channels or 4 UHD/4K channels (using HEVC compression superior to MPEG-4)
- Emergence of 4K and other high-bandwidth video technologies are driving demand for more C-Band capacity
- MVPD head ends (thousands) (including rural areas)
- > 1,000 broadcast affiliate stations, and over-the-top video distributors

- Cable operators receive and deliver to 51.9 million cable video customers using the 3.7-4.2 GHz band, relying on thousands of receive-only antennas, many of which are unregistered today.
- Comcast: 100's of C-Band receive ES, 80% of video programming using C-Band (148 transponders, 20 satellites, 86% transponders carry full-time feeds)
- Charter: Over 700 head-ends

Sources:

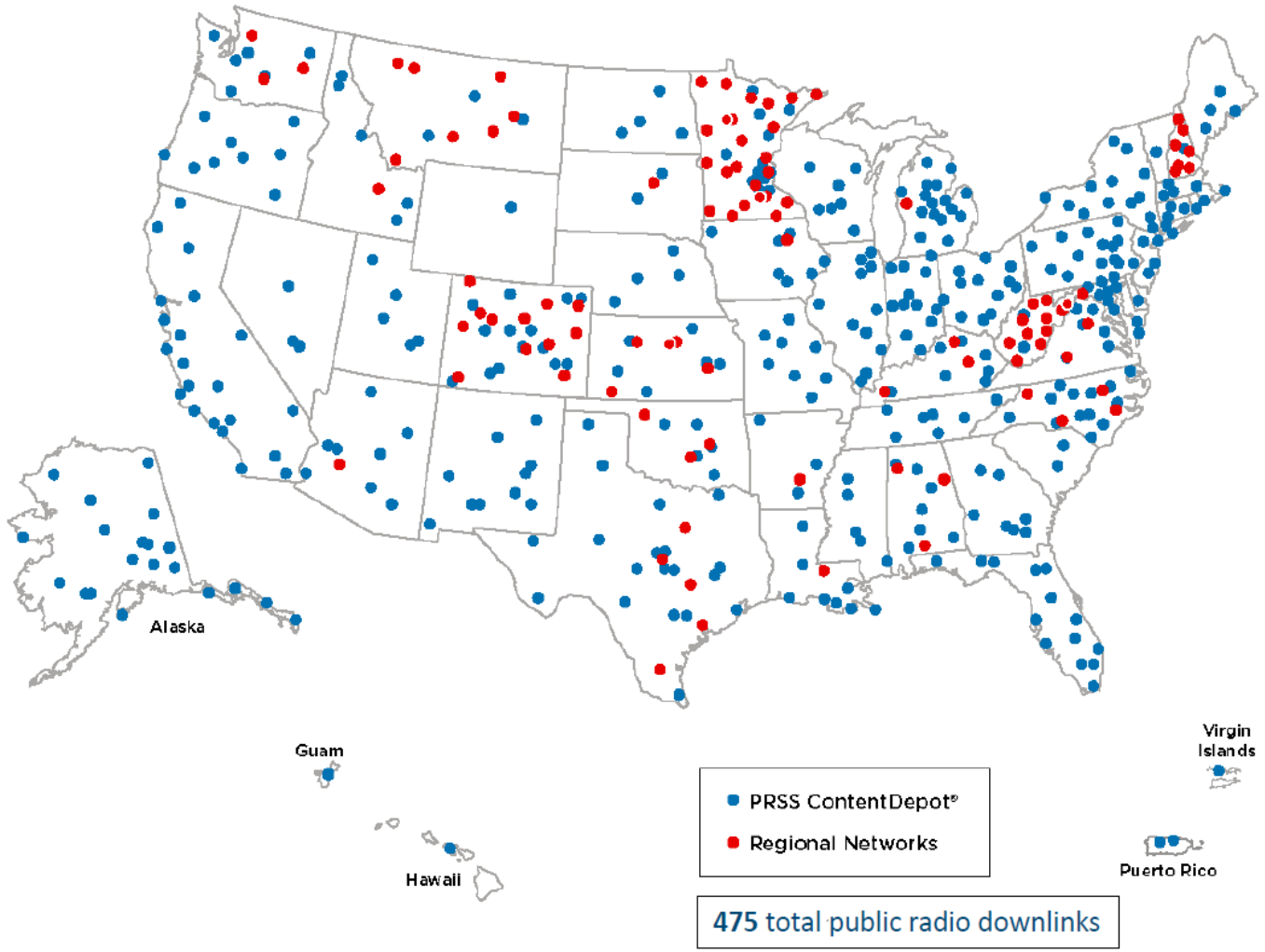
1. Comcast C-band Ex Parte McGrath, Dockets 17-183 18-122, May 10, 2018
2. Comcast-NBCU C-Band Ex Parte, Docket 18-122, June 8, 2018
3. Charter Mid-Band NOI Comments, Docket 17-183, October 3, 2017
4. Comments of the American Cable Association, Docket 17-183, October 2, 2017
5. https://www.lyngsat.com/america.html (information on satellite TV channels)

Cable Video Distribution System - Simplified View



Example: Incumbent Users (Radio broadcasters)

Public Radio C-Band Downlinks



475 total public radio downlinks

PRSS Leases A Satellite Transponder from Intelsat on C-Band

Downlink Frequencies

Galaxy 16/Transponder 1, C-Band:
Lower Frequency 3702.00 to
Upper Frequency 3738.00

Uplink Frequencies

Galaxy 16/Transponder 1, C-Band:
Lower Frequency 5927.00 to
Upper Frequency 5963.00

Getting Programs to Stations

VIA SATELLITE

LIVE & FILE PROGRAMS

VIA INTERNET

FILE PROGRAMS ONLY

Source: NPR ex-parte May 3, 2018 GN Docket Nos. 17-183, 18-122

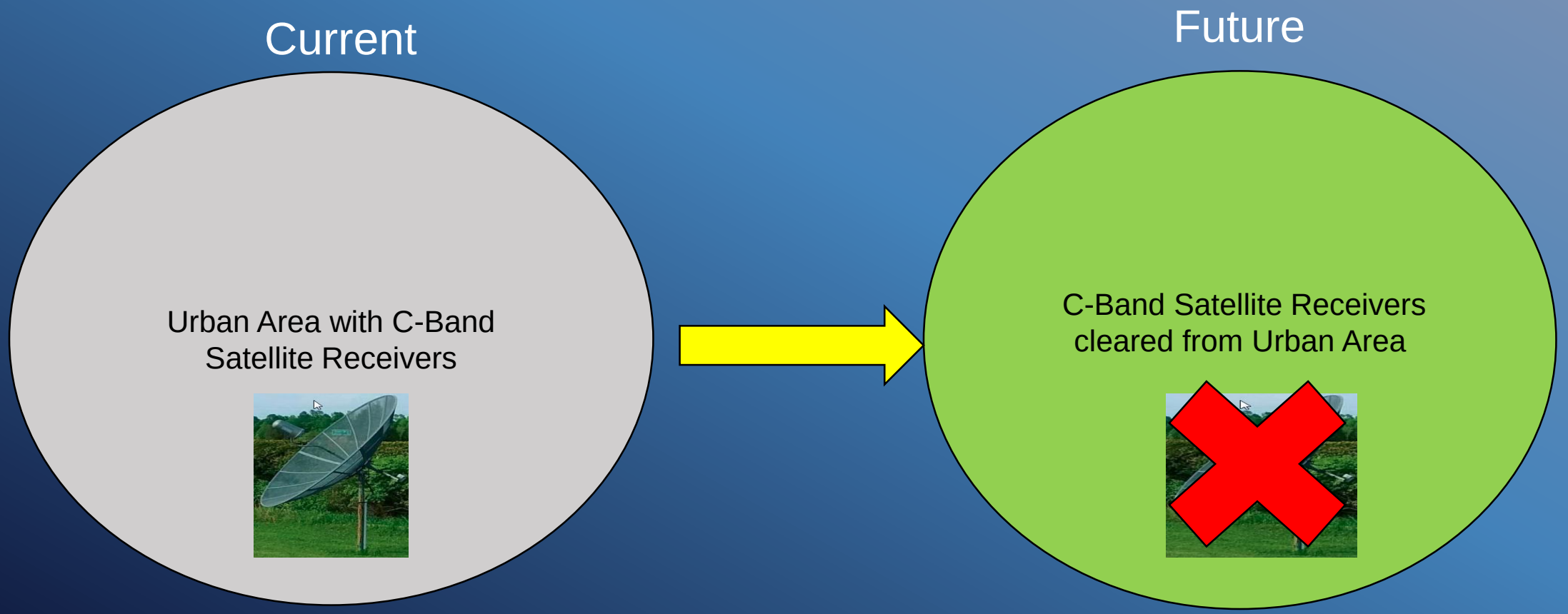
An Estimate of C-Band Receivers in Use

- Broadcast TV and Radio's infrastructure relies on satellite distribution to deliver content to and among its affiliate and owned and operated stations
- Content includes: News, talk, sports, entertainment and religious programming
- Satellite delivers programming to nearly every one of the more than 15,499 radio stations and 1,765 UHF and VHF television stations nationwide
- According to one estimate by LinkUp communications, there are over 27,000 C-band downlink locations nationally. Basis for estimate is use of C-Band downlinks in Panama City (Bay County), FL – population of 183,563 using 15 C-Band downlinks (i.e. 1 per 12,000 people). Extrapolation leads to nationwide estimate of 27000 receivers)
- Our models conservatively assumed the presence of 27,000 receivers (~575% the FCC NOI estimate of 4700 receivers)

Source: Ex-parte by LinkUp Communications Corporation, Society of Broadcast Engineers, Intelsat Corporation, SES Americom Inc., Docket Nos. 17-183, 18-122, May 24, 2018

Relocation of Satellite Users

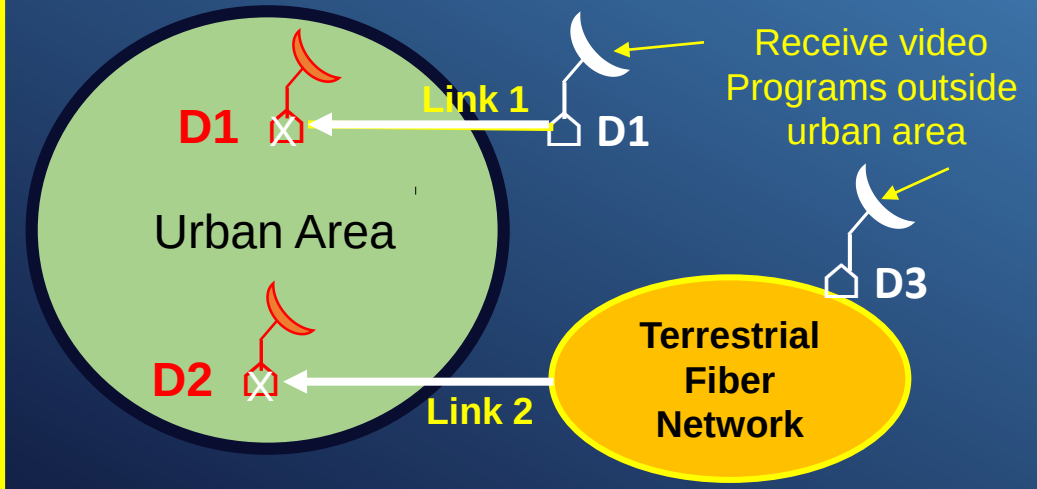
- Different classes of satellite users need to be cleared and/or relocated from C-Band.



Replacement options for C-Band satellite receivers in urban areas

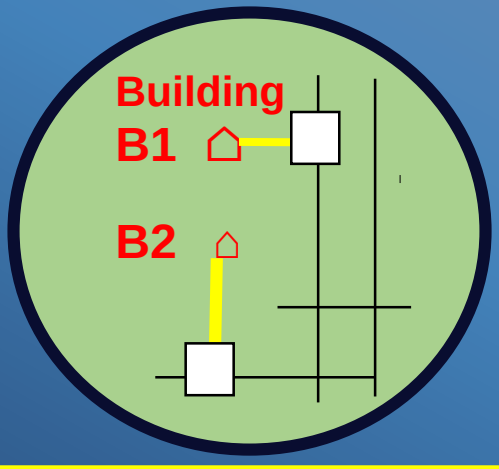
Option 1 (for Cable operators)

1. Relocate the receivers (Di's) to new locations outside urban area or connect to existing terrestrial fiber network
2. Provide fiber connectivity between the old and new locations
3. Local distribution networks are not changed (HFC networks)
4. End users keep same CPE equipment(s)



Option 2 (for enterprise/residential subscribers)

1. Replace the satellite receivers of existing, registered C-Band users by providing alternate high-speed fiber (Gbps+) links & fiber termination/ receiver
2. Abandon use of satellite dishes and associated receivers
3. Connectivity is provided to the nearest fiber access network in the urban area
4. Local distribution network inside the building is not changed



Relocation of Satellite Users

- Different classes of satellite users need to be cleared and/or relocated from C-Band.

Option 1: Relocation of Cable Broadcasters' Headend Receivers

- Relocate satellite head-ends from urban area to a location in a non-urban area.
  - Provide fiber connectivity to/from new satellite receiver location (~ 20 miles new fiber (see note below))
  - Extend the HFC network but no changes to the equipment of end users
  - Number of cable head-ends (total nationwide ~ 4800)
  - Expected number of cable head-ends in urban area – few hundreds or less
- Cable subscribers are not affected. No subscriber equipment changes are needed.

Note: A very conservative estimate of length of new fiber is used for connecting old and new satellite receiver locations. In urban / suburban markets, in addition to fiber network providers, there is a rich installed base of fiber backhaul / distribution networks used by wireless service providers and cable companies. These can be leveraged to lower the cost of new fiber installation.

Relocation of Satellite Users

Option 2: Relocation of C-Band Receivers from an Urban Area with Fiber Access

- Provide alternate access link to satellite subscriber (eliminates satellite link) – optical fiber
  - Provide fiber connectivity to the customer premises using FTTH (or equivalent access speed of 1 Gbps) (high probability in urban area, > 90 % in urban Chicago)

or

  - Seek new connectivity using “nearest” fiber access provider in the area
    - Cost of providing fiber access will depend on:
      - Specific location of existing satellite receiver
      - Proximity to get connected to an existing fiber network”
      - Variety of other factors (detailed next)

Factors Affecting Fiber Optic Installation Costs

1. Proximity of customer premises to the nearest active fiber line is a major factor.
   Does the fiber network run through or near the customer premises?

2. Existence of conduit in the customer premises
   - Take advantage of an existing conduit to lower the cost of adding new capacity to the customer premises
   - Use of existing conduit requires sufficient space to install fiber - substantially simpler & cheaper
   - Physical placement and route of fiber cable will have a major impact on the costs of its installation (winding paths more challenging than straight cables)

3. Physical obstacles in the way to the customer premises
   - The nature of the physical terrain that the fiber needs to traverse to reach the customer premise – a significant factor
   - In urban / suburban areas, crossing a state highway or major road to bring the nearest fiber to the customer premises will significantly impact the overall costs
   - Obstacles such as historic buildings/landmarks near the customer premises could potentially impact the costs of fiber installation, depending on the route fiber needs to take to the customer premises

Factors Affecting Fiber Optic Installation Costs (contd.)

4. Availability of space in the telco closets

- When the fiber is brought to a customer premises, if a telecommunications room with the necessary space for installation is already available, it can lower installation costs

5. Availability of sufficient power for fiber technology

- Availability of sufficient power for fiber accessible from telecommunications room and/or an emergency generator for backup purposes
- Save costs of introducing additional power capabilities

6. How many different paths to the customer premises can the fiber cable take?

- Fiber can be brought into a customer premise through two separate entry points. A primary fiber connection and a secondary fiber connection to mitigate potential outages if the primary fiber circuit is cut. While this is a rare occurrence, installing through two entrance points removes risk and improves reliability. This higher cost option may be needed for enterprises and/or business users, that may use C-Band receivers.

Cost of Establishing Fiber Connectivity

Cost of connecting a customer premises to the nearest fiber transit point of a provider depends on following factors.

- Distance (x miles)
- New construction or Existing fiber infrastructure (typical of urban / metro areas):
  - Terrain that the fiber would have to traverse
    - Bury the fiber underground (per mile: $ 45,000-50,000 for construction labor + $ 9,250 material)
    - Overground (stringing across poles)
      - Per mile: $ 9,000 for labor + $ 3,500 material plus
      - Pole attachment costs – “make-ready” costs + pole attachment rental costs (recurring)
    - Cost of leasing fiber from transit provider (1Gbps – $ 3,000 / month)
- Additional cost if backup connectivity to transit provider is needed for reliability

Note: Cost factors are based on figures noted in the following:
Comments of the American Cable Association, GN Docket 17-183, October 2, 2017.

Scope of Relocation Effort: Top 30 Metropolitan Areas

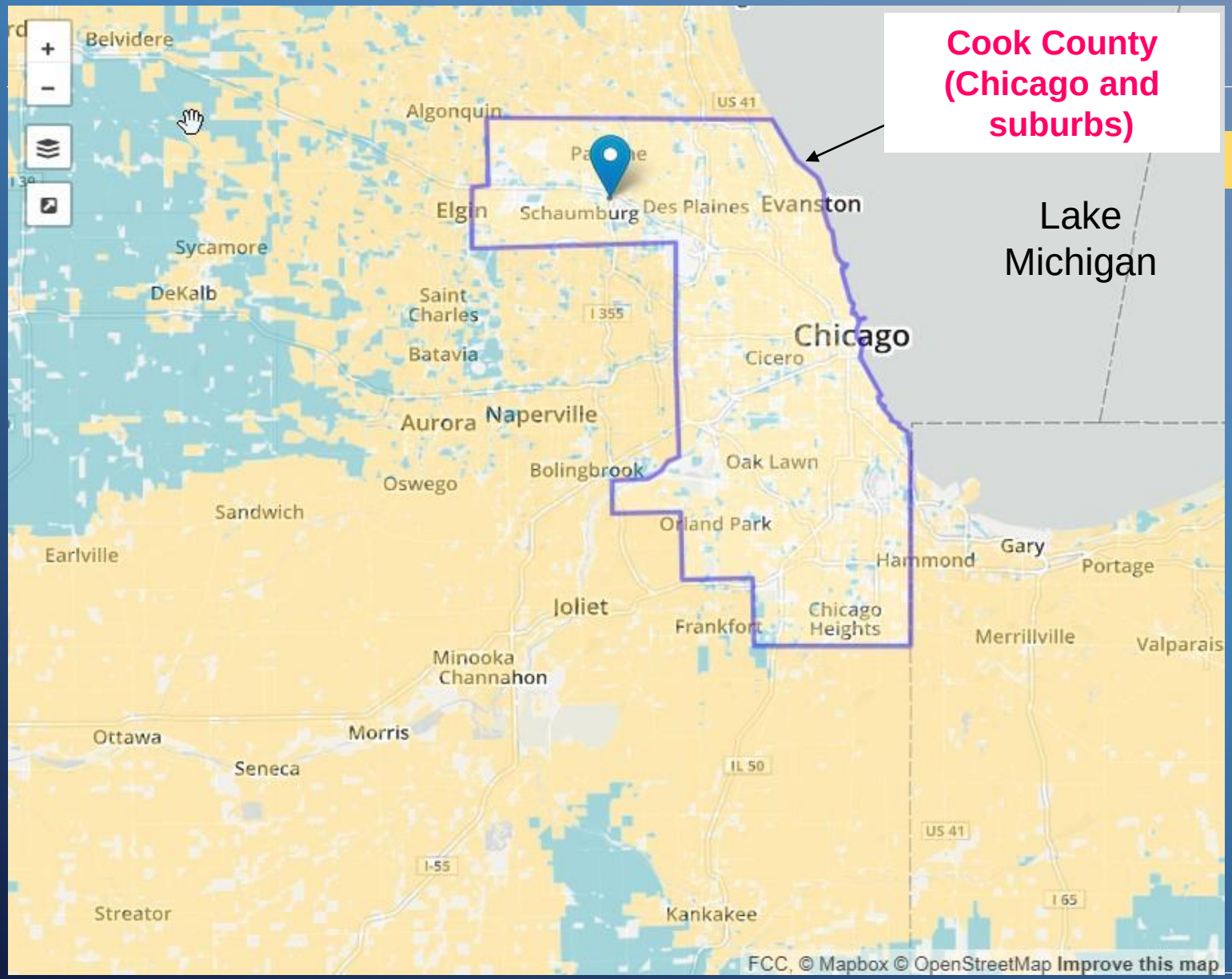
(urban and suburban areas with at least 2 million population)

Rank	Metropolitan statistical area	2017 Estimate
1	New York-Newark-Jersey City, NY-NJ-PA MSA	20,320,876
2	Los Angeles-Long Beach-Anaheim, CA MSA	13,353,907
3	Chicago-Naperville-Elgin, IL-IN-WI MSA (*)	9,533,040
4	Dallas-Fort Worth-Arlington, TX MSA	7,399,662
5	Houston-The Woodlands-Sugar Land, TX MSA	6,892,427
6	Washington-Arlington-Alexandria, DC-VA-MD-WV MSA	6,216,589
7	Miami-Fort Lauderdale-West Palm Beach, FL MSA	6,158,824
8	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD MSA	6,096,120
9	Atlanta-Sandy Springs-Roswell, GA MSA	5,884,736
10	Boston-Cambridge-Newton, MA-NH MSA	4,836,531
11	Phoenix-Mesa-Scottsdale, AZ MSA	4,737,270
12	San Francisco-Oakland-Hayward, CA MSA	4,727,357
13	Riverside-San Bernardino-Ontario, CA MSA	4,580,670
14	Detroit-Warren-Dearborn, MI MSA	4,313,002
15	Seattle-Tacoma-Bellevue, WA MSA	3,867,046

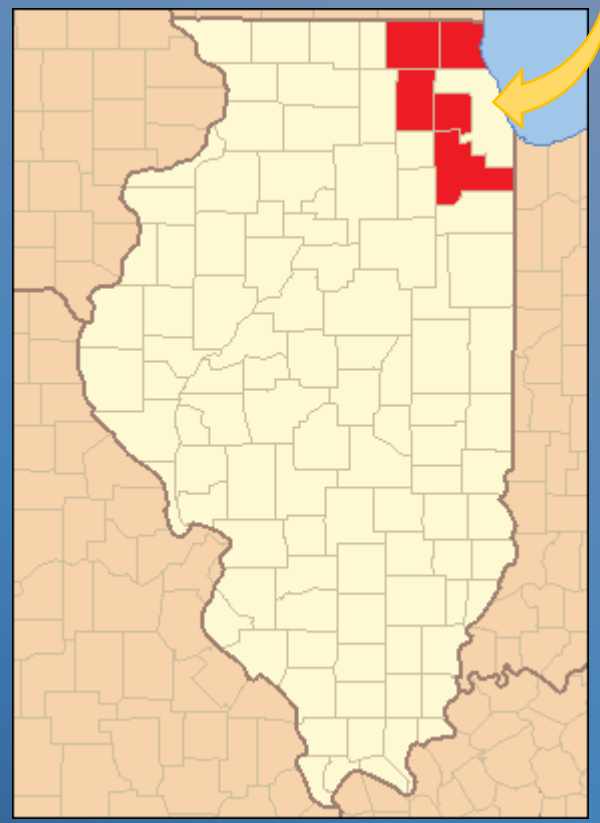
Rank	Metropolitan statistical area	2017 Estimate
16	Minneapolis-St. Paul-Bloomington, MN-WI MSA	3,600,618
17	San Diego-Carlsbad, CA MSA	3,337,685
18	Tampa-St. Petersburg-Clearwater, FL MSA	3,091,399
19	Denver-Aurora-Lakewood, CO MSA	2,888,227
20	Baltimore-Columbia-Towson, MD MSA	2,808,175
21	St. Louis, MO-IL MSA	2,807,338
22	Charlotte-Concord-Gastonia, NC-SC MSA	2,525,305
23	Orlando-Kissimmee-Sanford, FL MSA	2,509,831
24	San Antonio-New Braunfels, TX MSA	2,473,974
25	Portland-Vancouver-Hillsboro, OR-WA MSA	2,453,168
26	Pittsburgh, PA MSA	2,333,367
27	Sacramento–Roseville–Arden-Arcade, CA MSA	2,324,884
28	Las Vegas-Henderson-Paradise, NV MSA	2,204,079
29	Cincinnati, OH-KY-IN MSA	2,179,082
30	Kansas City, MO-KS MSA	2,128,912

https://en.wikipedia.org/wiki/List_of_metropolitan_statistical_areas

This analysis is focused on Chicago and surrounding areas in Cook County (a subset of the 3rd ranked MSA in above table)



Cook County, IL
Total Population: 5,194,675



(Cook, DuPage, Kane, Lake, McHenry, and Will)

Chicago Analysis

- Providers of speeds (up to 1 Gbps) are present in a large fraction of the urban Chicago area. Number of carriers providing termination at the customer premises varied from 1 to 3 in all the zip code areas that we sampled at random.

- An incumbent user with C-Band satellite receiver located in any of these zip code areas can avail of the Gbps service from one of the commercial providers serving the area.

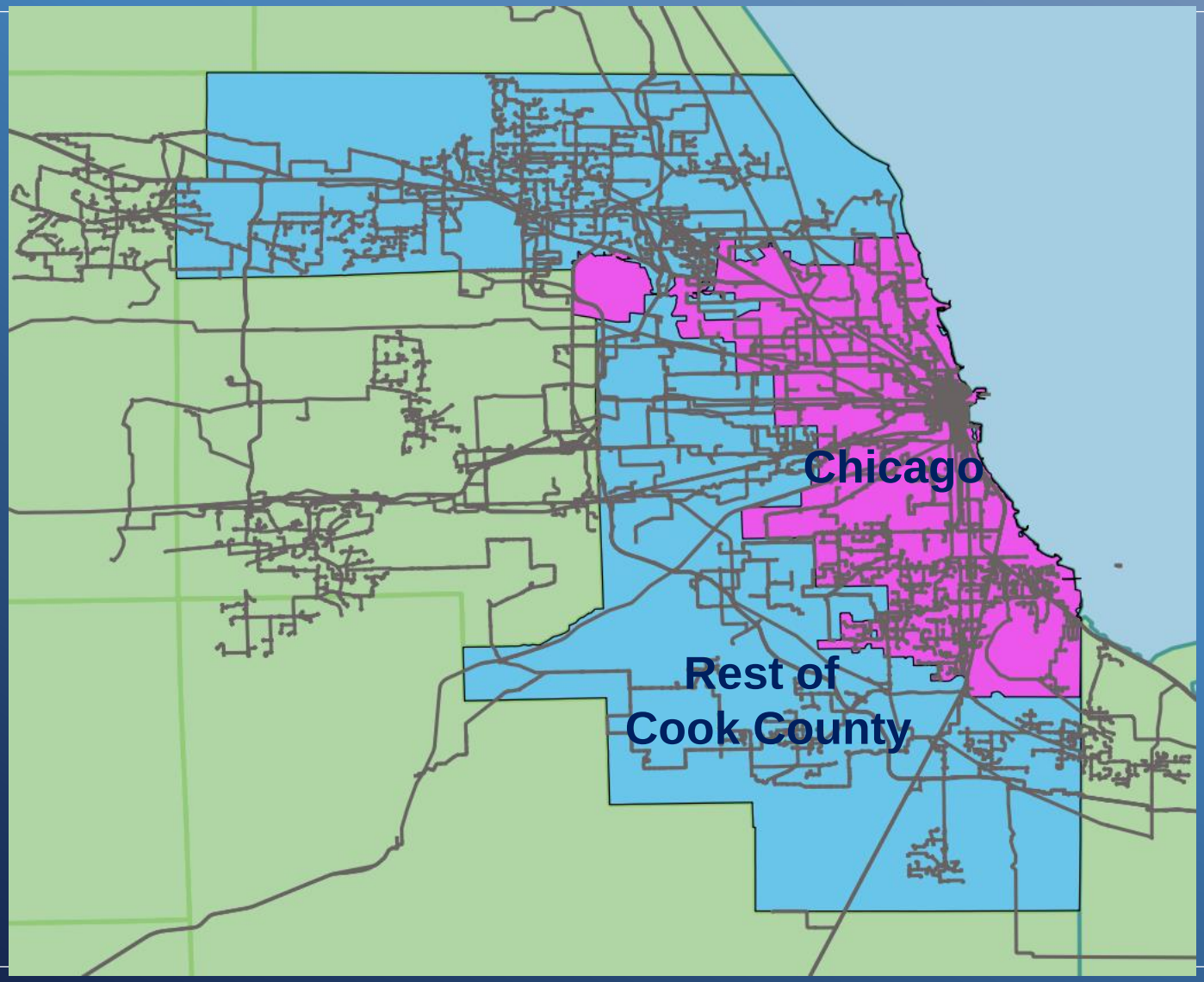
- An incumbent user with a C-Band satellite receiver but no Gbps service available at his/her premise (using fiber and/or cable distribution) has the option to securing a fiber connectivity at a cost.

Candidate Fiber Providers in Chicago

Company	Maps	Lit/Dark	Comments
Crown Castle	Chicago	Both	
Level 3 Communications	Chicago	Both	Google Maps interface, zoom in
Mirovia Networks	Chicago	Lit	
Uniti Fiber	Chicago	Both	
US Signal	Chicago Area, Rockford	Both	Flash map: click on Chicago for detailed map.
Windstream	Chicago Area	Both	
WOW! Businesss	Chicago Area	Lit	KMZ
Zayo	Chicago Area	Both	
Atlantic Metro		Lit	
Cogent		Lit	On-net buildings tool
XO		Both	

(Source: https://www.telecomramblings.com/metro-fiber-maps/chicago/)

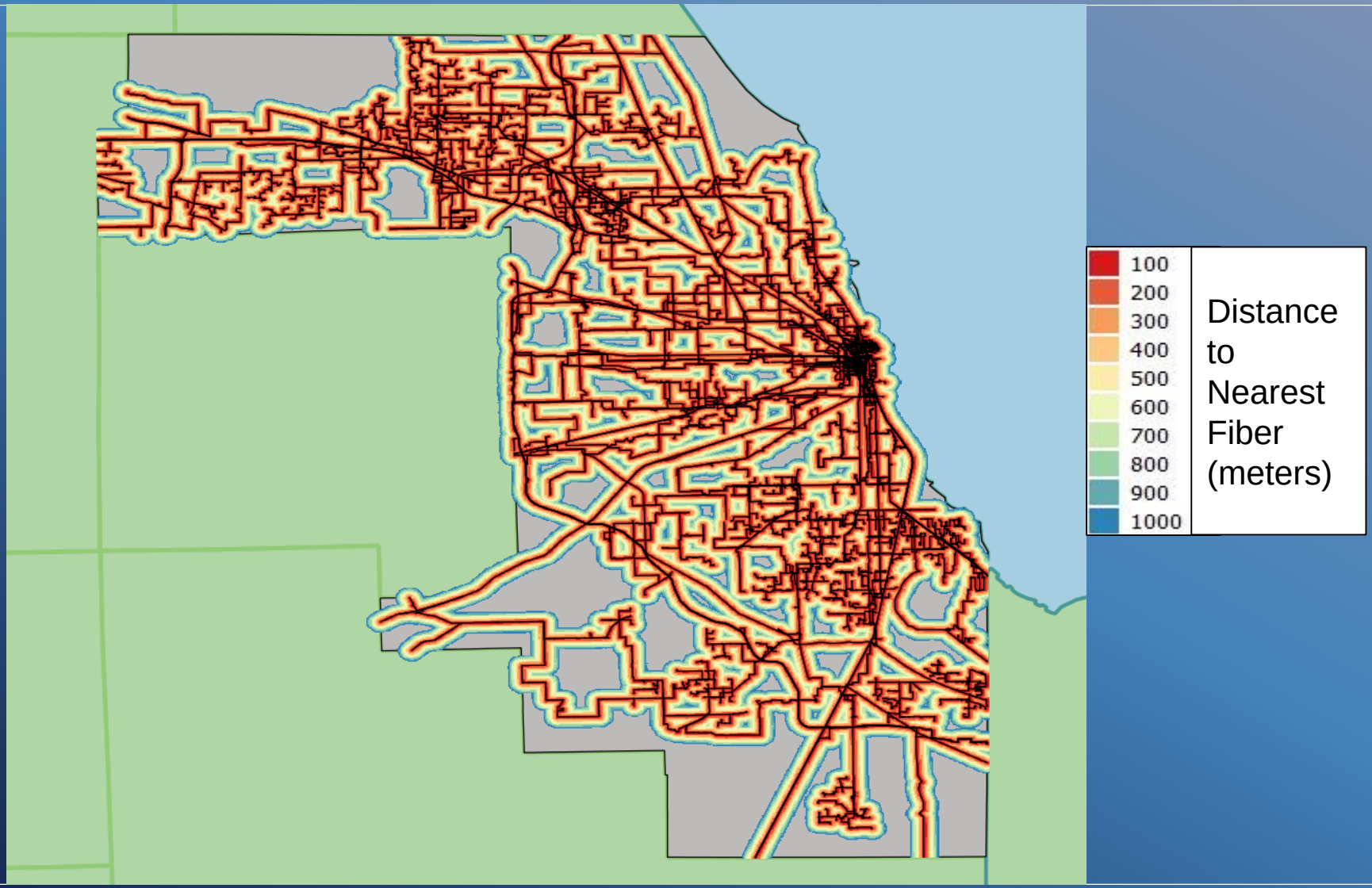
4 Fiber Networks Combined



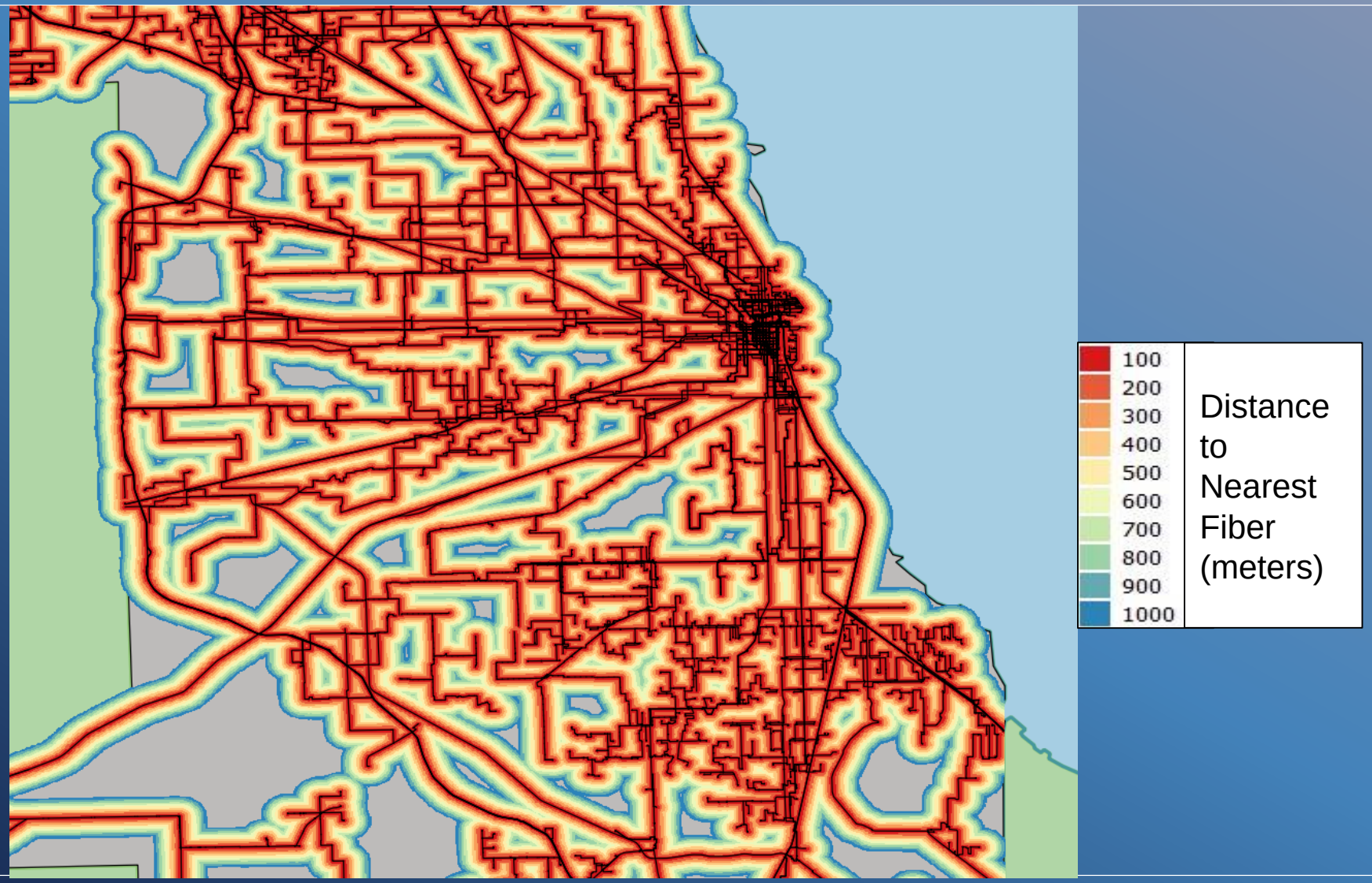
Fiber Providers included:
1. Crown Castle Fiber
2. Windstream
3. Wide Open West
4. Zayo

Note: Map could be enriched further if fiber deployment data of additional providers becomes available

Heat Map of Proximity to a Fiber Provider



Close up view of Proximity Heat Map



ISP's in Chicago Area: An estimate of coverage and speed

Summary of Internet Providers in Chicago	https://broadbandnow.com/Illinois/Chicago			
	Provider	Type	Coverage	Speed
1	AT&T Internet	DSL and Fiber	99.8%+	1,000 Mbps
2	XFINITY from Comcast	Cable	96.2%+	987 Mbps
3	RCN	Cable	82.1%+	1,000 Mbps
4	Comcast Business	Cable	84.2%+	987 Mbps
5	AT&T	DSL and Fiber	100%	1,000 Mbps
6	Level 3 Communications	Fiber	90.0%+	1,000 Mbps
7	Crown Castle Fiber	Fiber	83.3%+	1,000 Mbps
8	RCN Business	Cable and Fiber	49.1%+	1,000 Mbps
9	Verizon Business	Copper	44.1%+	1,000 Mbps
10	Cogent Communications	Fiber	31.7%+	1,000 Mbps
11	Zayo	Fiber	19.1%+	400 Mbps
12	Towerstream	Fixed Wireless	7.8%+	1,000 Mbps

1. The above information is one source of information on ISP's serving Chicago / Cook County. However, we rely on our own analysis to estimate availability of fiber connectivity and cost estimation.
2. On a nationwide basis, the NCTA has noted availability of Cable's DOCSIS 3.0 high-speed internet networks to more than 85% of U.S. households. https://www.ncta.com/chart/availability-of-docsis-30-high-speed-internet-service. The cable industry is now deploying even faster (10 Gbps service) based on DOCSIS 3.1. It is reasonable to expect about 90% of U.S. households can get at least 1 Gbps service.

Approach to Estimating Cost for providing fiber to incumbent users of C-Band Receivers

For each urban area, perform the following steps

1. Determine number of fiber providers
2. Determine details of individual providers' fiber infrastructure
3. Combine the various providers infrastructure maps
4. Generate fiber proximity heat maps indicating areas within specified distance ranges from available providers
5. Pick a specified number of locations (in an urban area) – random or specified
6. For each location X, determine the "distance" to a combined fiber network
7. Determine the cost of providing fiber access to location X
8. Compute the average cost of providing fiber access

Cost Model for Option 1

(Conservative cost estimates for relocating cable head ends of cable operators)

Connectivity Costs		
Link 1	**Average length of fiber connectivity (miles) from existing to new location of cable head ends**	**20**
	Cost of fiber connectivity ($ per foot)	**$ 20**
	Cost of connecting old & new headend locations with fiber	**$ 2,112,000**
Link 2	**Average length of fiber connectivity (miles) to an existing terrestrial fiber network used for video distribution**	**2**
	Cost of connecting to existing terrestrial fiber network	**$ 211,200**
	Probability Link 1 is used (%)	**50**
	Probability Link 2 is used (%)	**50**
	Expected fiber costs for relocating cable head ends	**$ 1,161,600**
Headend Equipment Replacement Costs	**Probability of satellite headend being relocated**	**0.5**
	Estimated number of satellite head ends in Cook County	**71**
	Average cost of satellite headend ($)	**$ 50,000**
	Expected replacement cost of satellite head ends ($)	**$ 1,775,000**

Cost Model for Option 2
(Conservative cost estimates for replacing C-Band receivers)

Cost Model (urban Chicago) All costs are in U.S. Dollars	
US Population (million)	325
Chicago population (million)	2.7
Total # C-Band Receivers (worst case estimate)	27000
Percentage of population in urban Chicago	0.83
# of Satellite C-Band Receivers	224
Average # of city blocks to fiber access	1
Length of Chicago city block = 660 x 330 feet	495
Average length of fiber (feet)	495
Cost per foot of fiber wire ($ per foot) (see Note 1 below)	$ 110
Probability 1 Gbps available (%)	90
Expected Cost of wiring with fiber	$ 5,445
Expected Cost of replacing satellite w/ fiber for all existing C-band dishes in Chicago	**$ 1,219,680**

Cost Model (Cook County - Chicago and suburbs) All costs are in U.S. Dollars	
US Population (million)	325
Cook County (including Chicago) population (million)	5.194
Total # C-Band Receivers (worst case estimate)	27000
Percentage of population in Cook County (including Chicago)	1.598
# of Satellite C-Band Receivers	431
Average # of county blocks to fiber access	3
Length of a county block = 660 feet	660
Average length of fiber (feet)	1980
Cost per foot of fiber wire ($ per foot)	$ 20
Probability 1 Gbps available (%) (see Note 2 below)	70
Expected Cost of wiring with fiber	$ 11,880
Expected Cost of replacing satellite w/ fiber for all existing C-band dishes in Cook County	**$ 5,120,280**

Note 1: Cost per foot of fiber is ~ $ 11 per foot (according to American Cable Association filing (cited earlier). We make a conservative assumption the cost per foot in urban Chicago is 10 times the ACA estimate.

Note 2: We make conservative assumption of 70% availability of 1 Gbps service in Cook County (compared to estimate of > 85% nationwide availability of cable DOCSIS 3.0 + offering 1 Gbps or greater service)

Cost Model Summary

Chicago and surroundings (Cook County)

Option 1: Relocating cable head ends of cable operators (from Cook County)

- Expected fiber costs for relocating cable head ends = $ 1,161,600
- Expected replacement cost of satellite head ends ($) = $ 1,775,000
- Total estimated cost to cable operators = $ 2,936,600

Option 2: Replacing C-Band receivers of individuals / enterprise customers

- Expected Cost of replacing satellite w/ fiber for all existing dishes in Chicago = $ 1,219,680
- Expected Cost of replacing satellite w/ fiber for all existing dishes in Cook County = $ 5,120,280

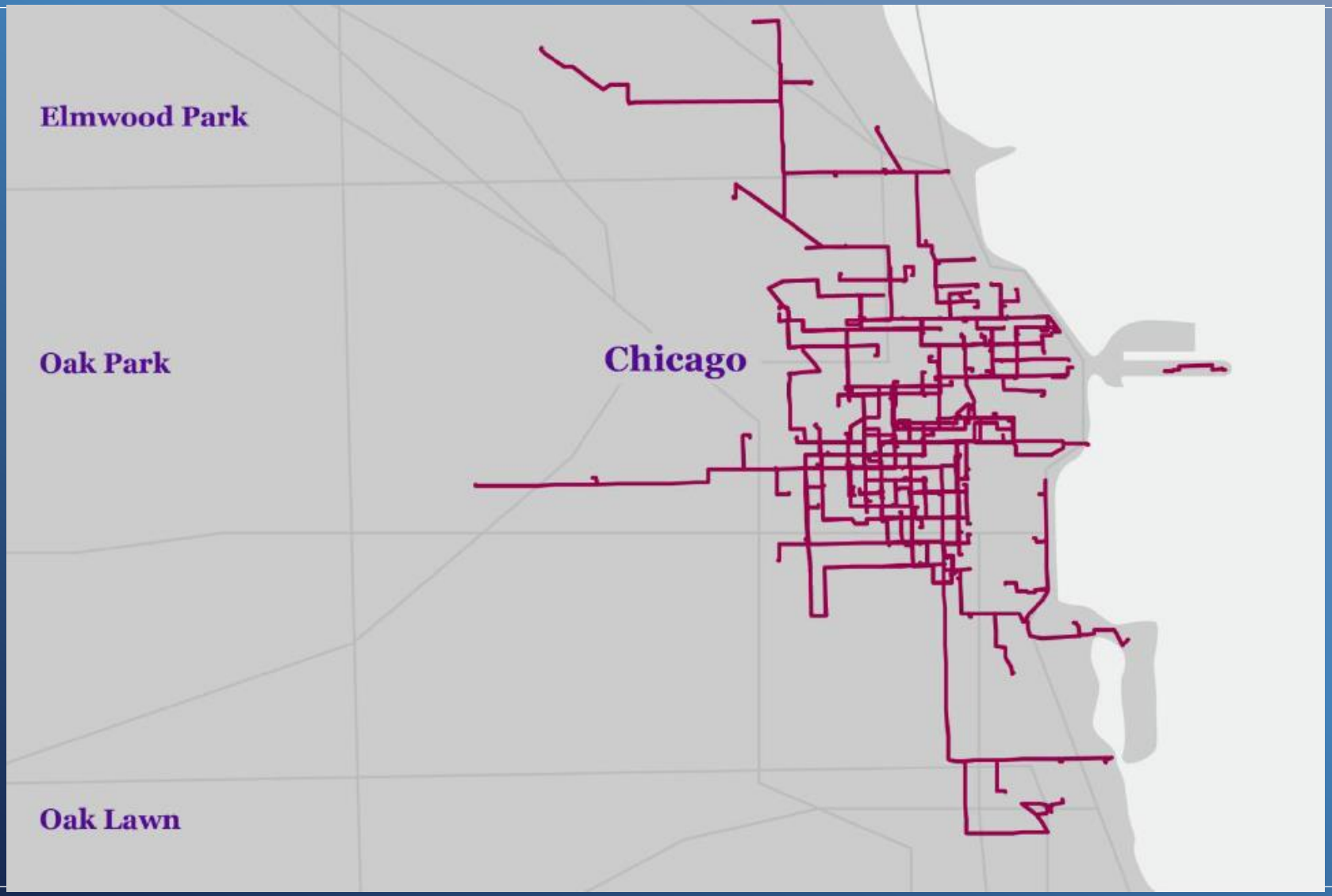
Conclusions

- As a result of our analysis, replacement of satellite by fiber should be feasible based on the availability of fiber and equipment replacement costs
- Results show the economic viability of clearing C-Band spectrum from urban / suburban areas in Chicago and surroundings market
- Economic analysis for other urban or metropolitan areas will need a case-by-case review; It is reasonable to expect the viability of clearing C-Band spectrum will hold in other major markets as well.
- Rural markets are not significantly affected by the relocation methods. They may continue use of C-Band spectrum with minimal or no impact to the existing C-Band customers / users.
- Improvement of satellite resource utilization through optimized assignment of satellite transponder capacity as a function of time, space and frequency has potential to clear greater amount of spectrum for 5G terrestrial use.

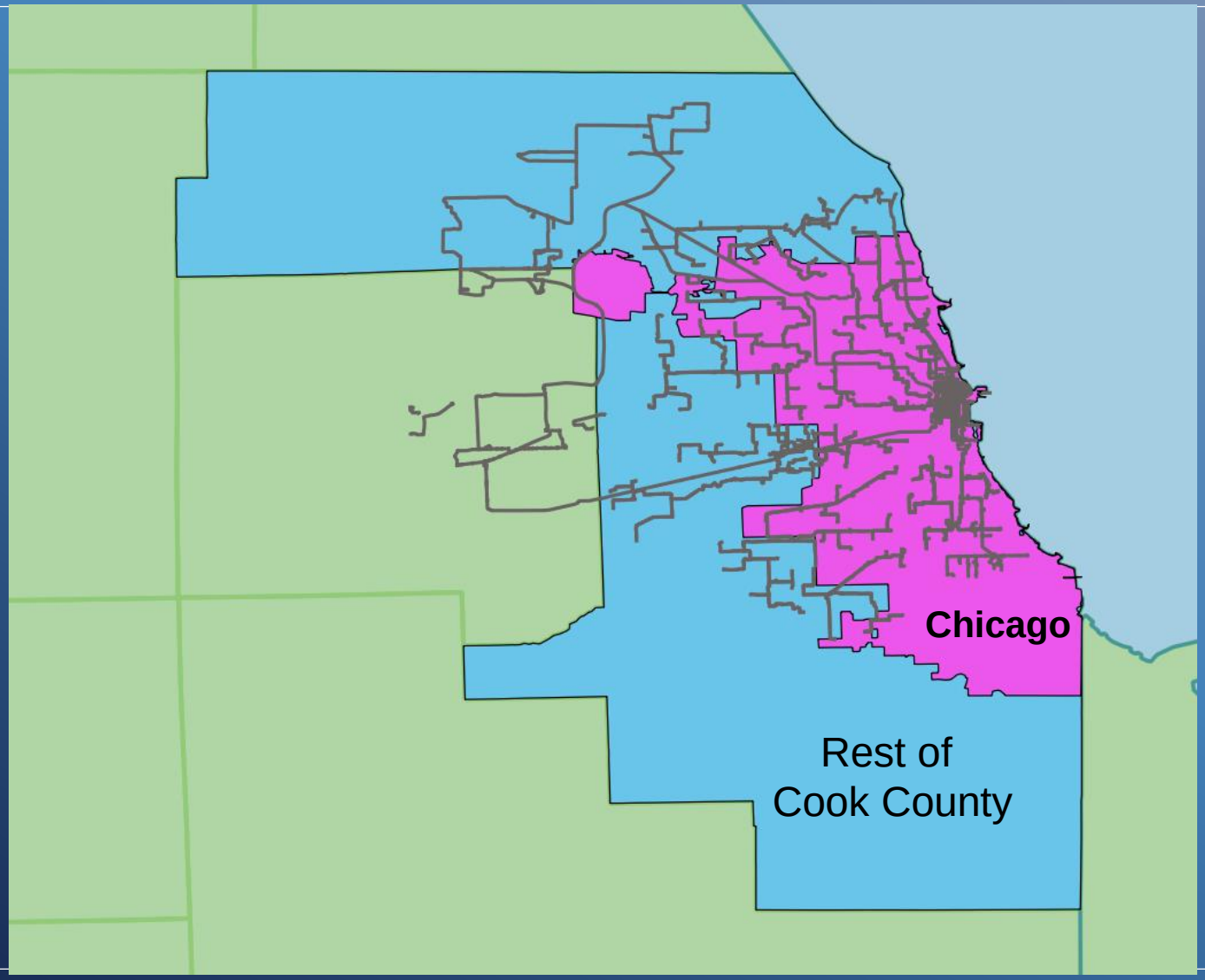
Thank You

BACKUP

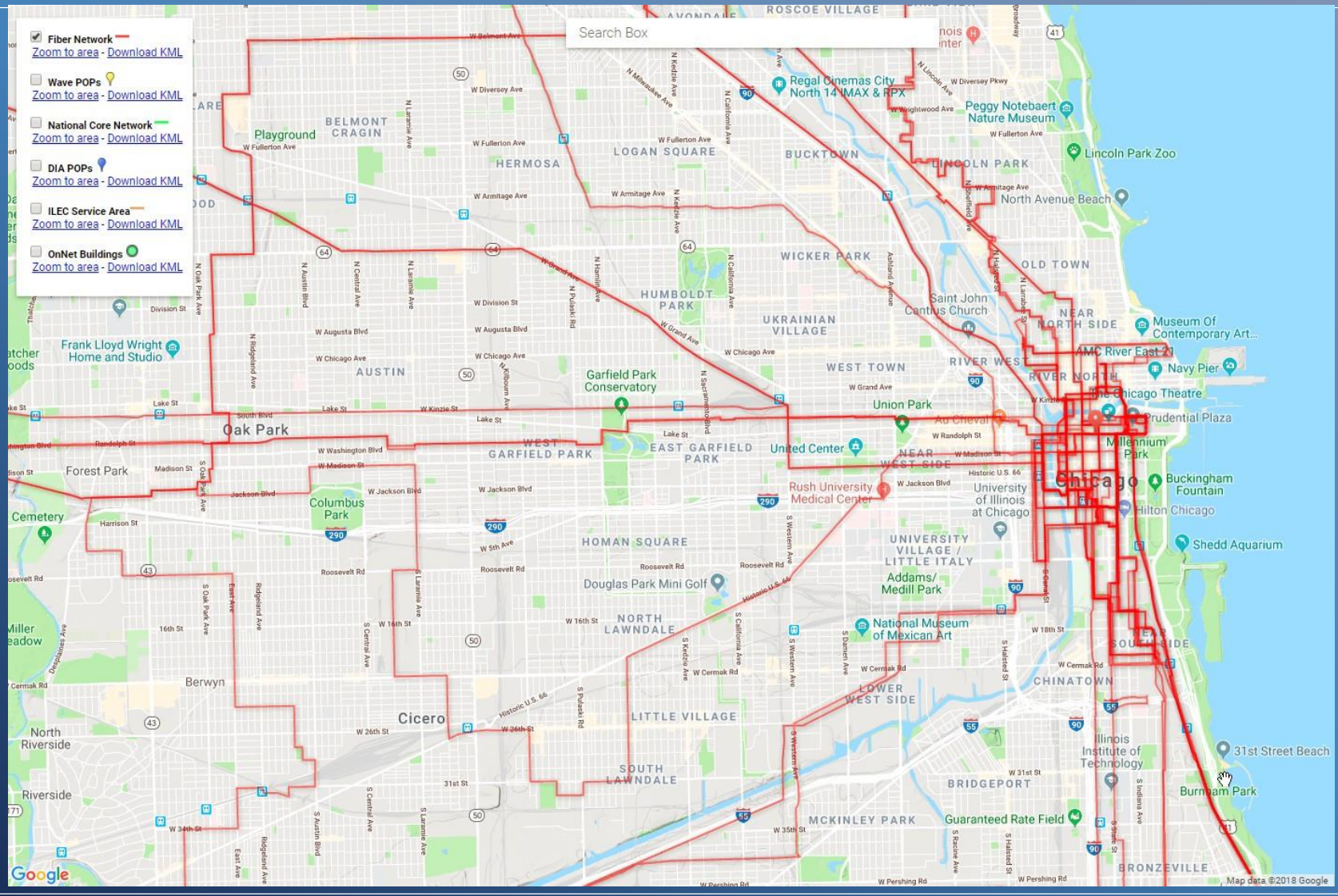
Provider 1: Crown Castle Fiber Network



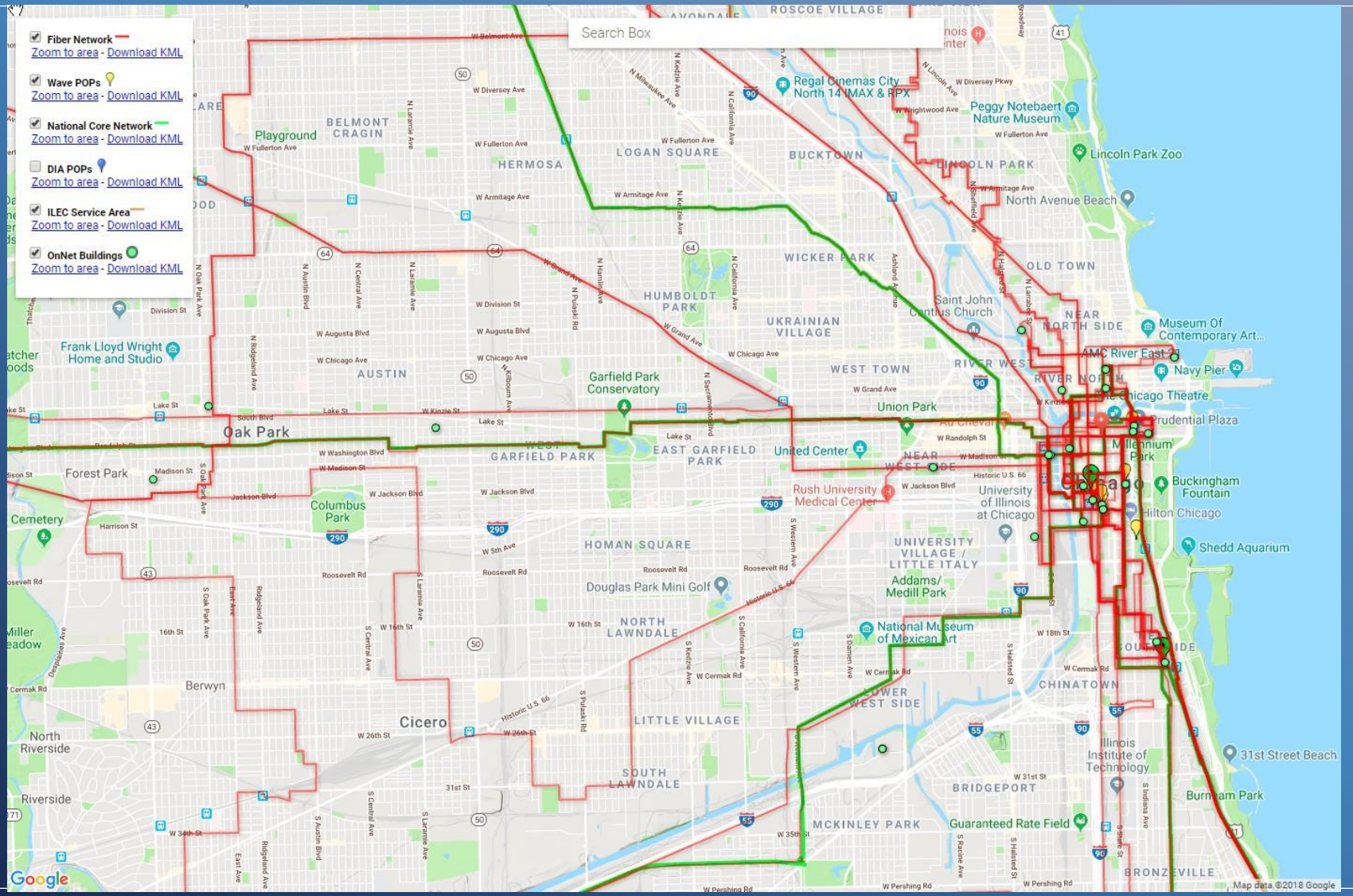
Provider 1: Crown Castle Fiber Network (contd.)



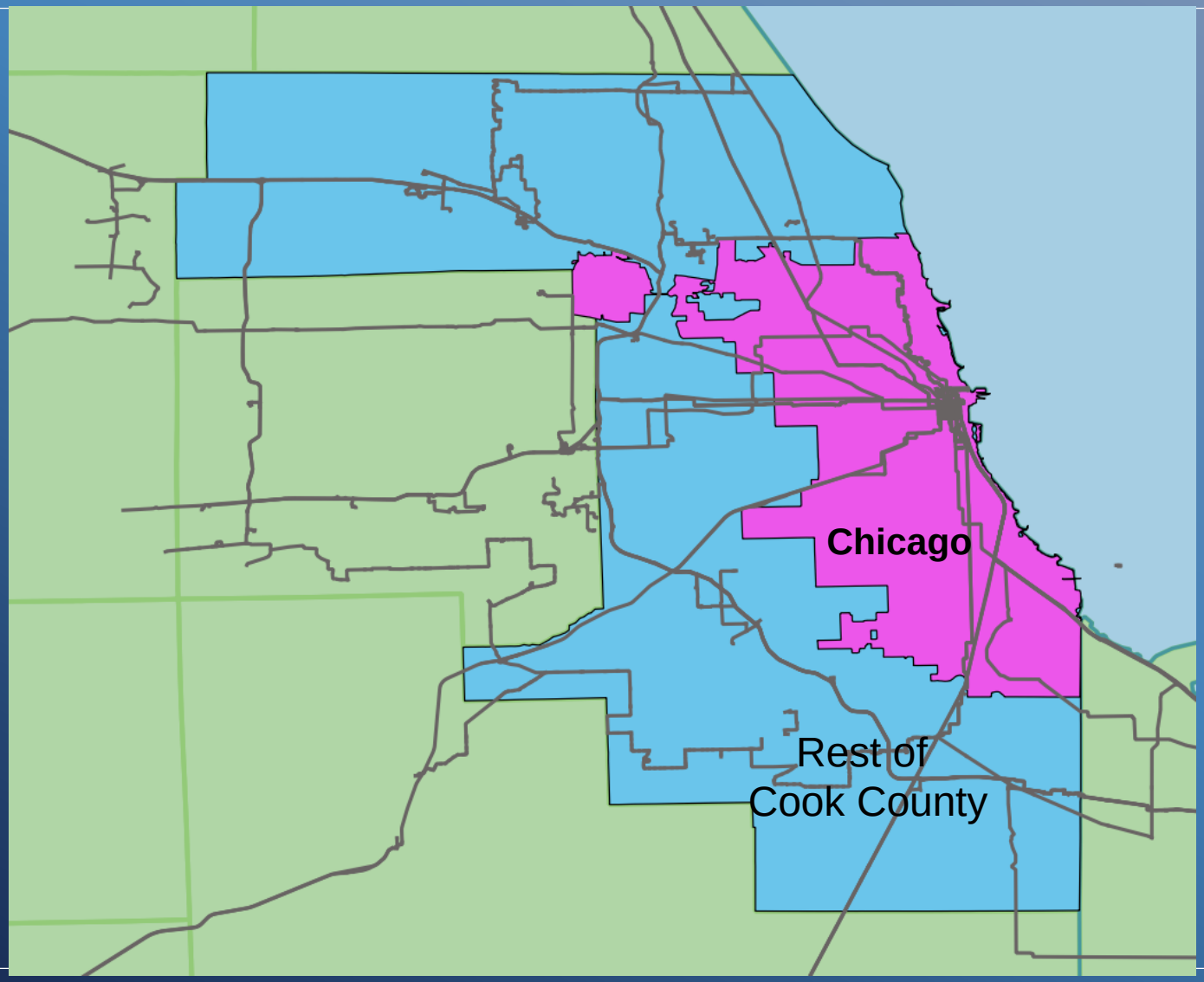
Provider 2: Windstream Fiber Network



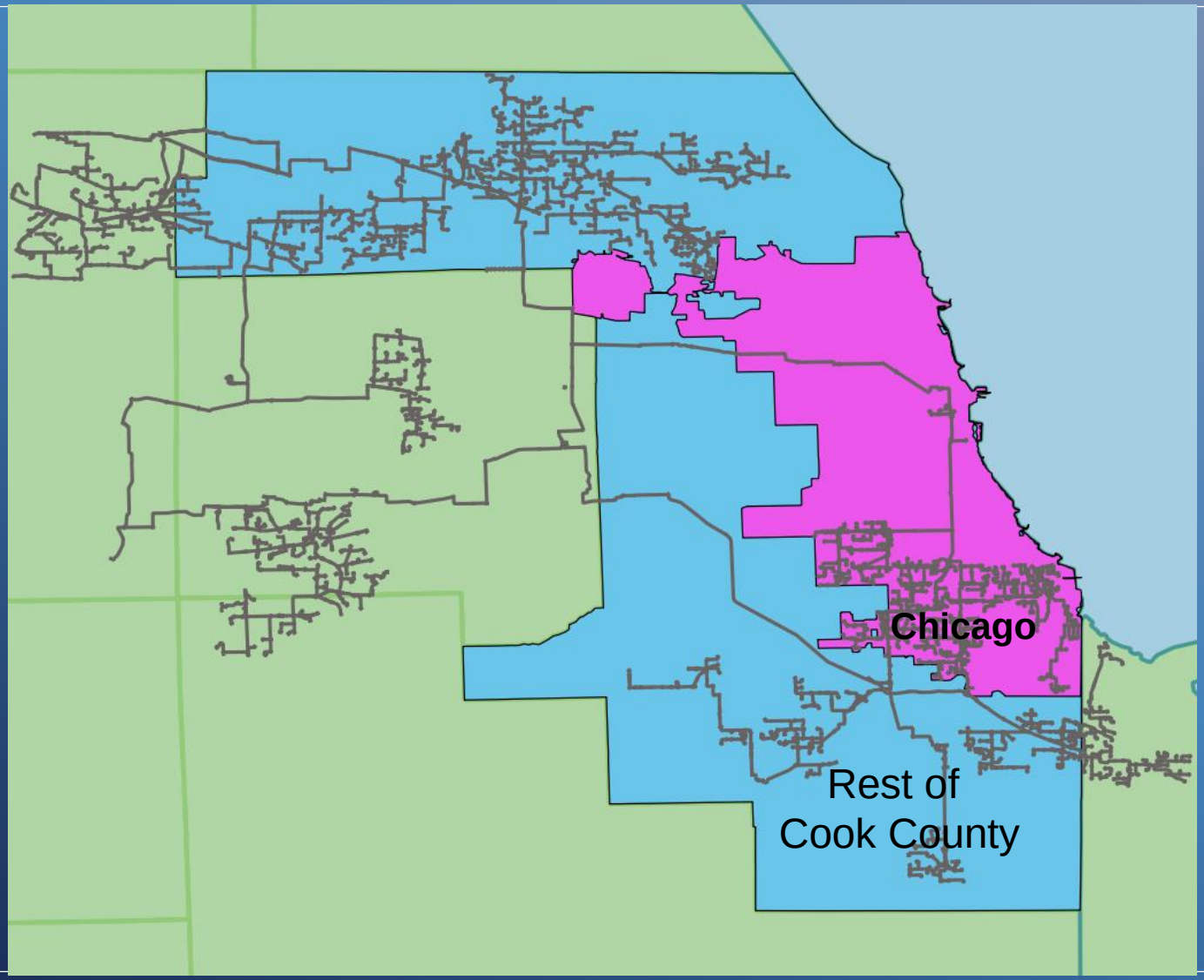
Provider 2: Windstream Fiber Network (additional detail)



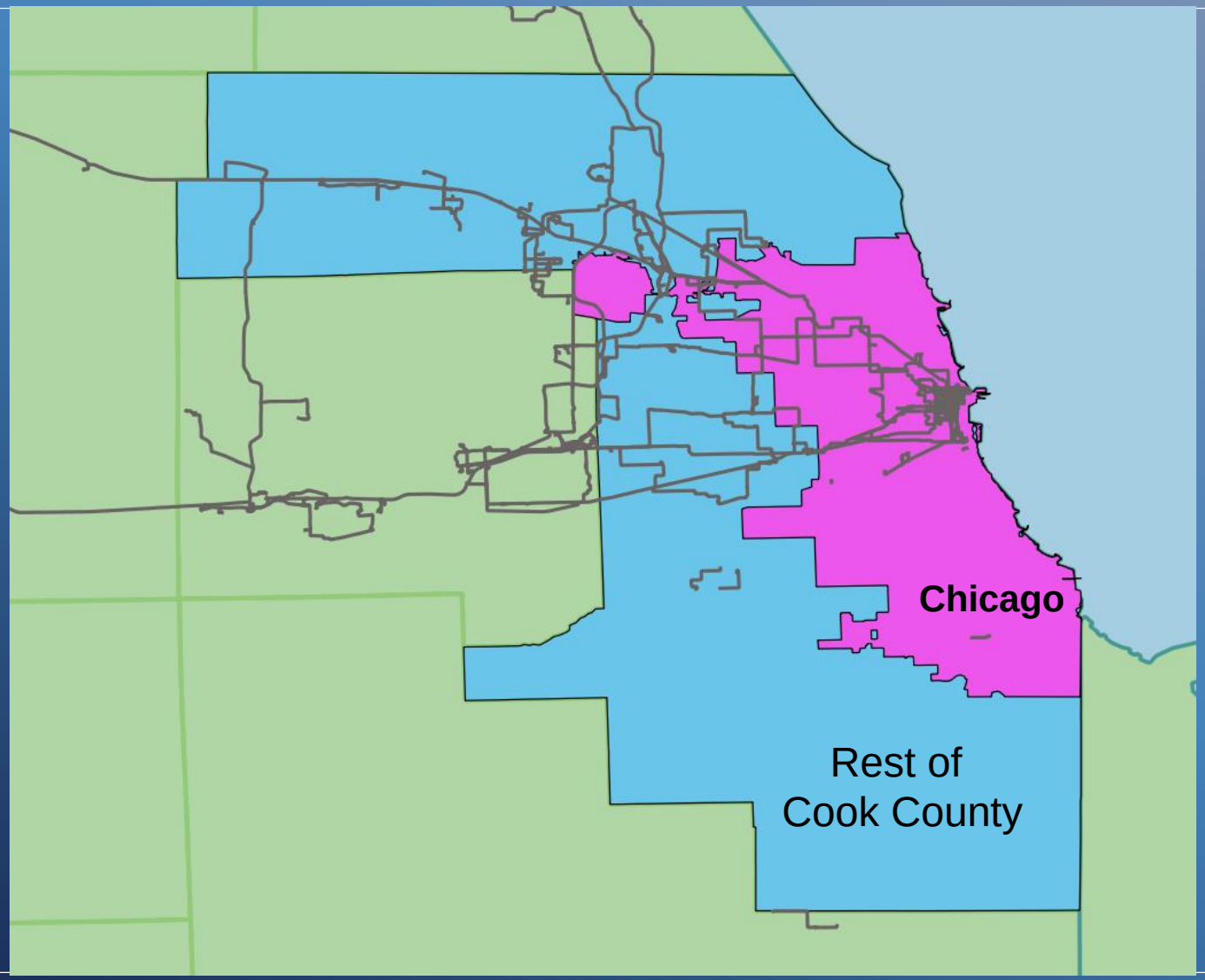
Provider 2: Windstream Fiber Network



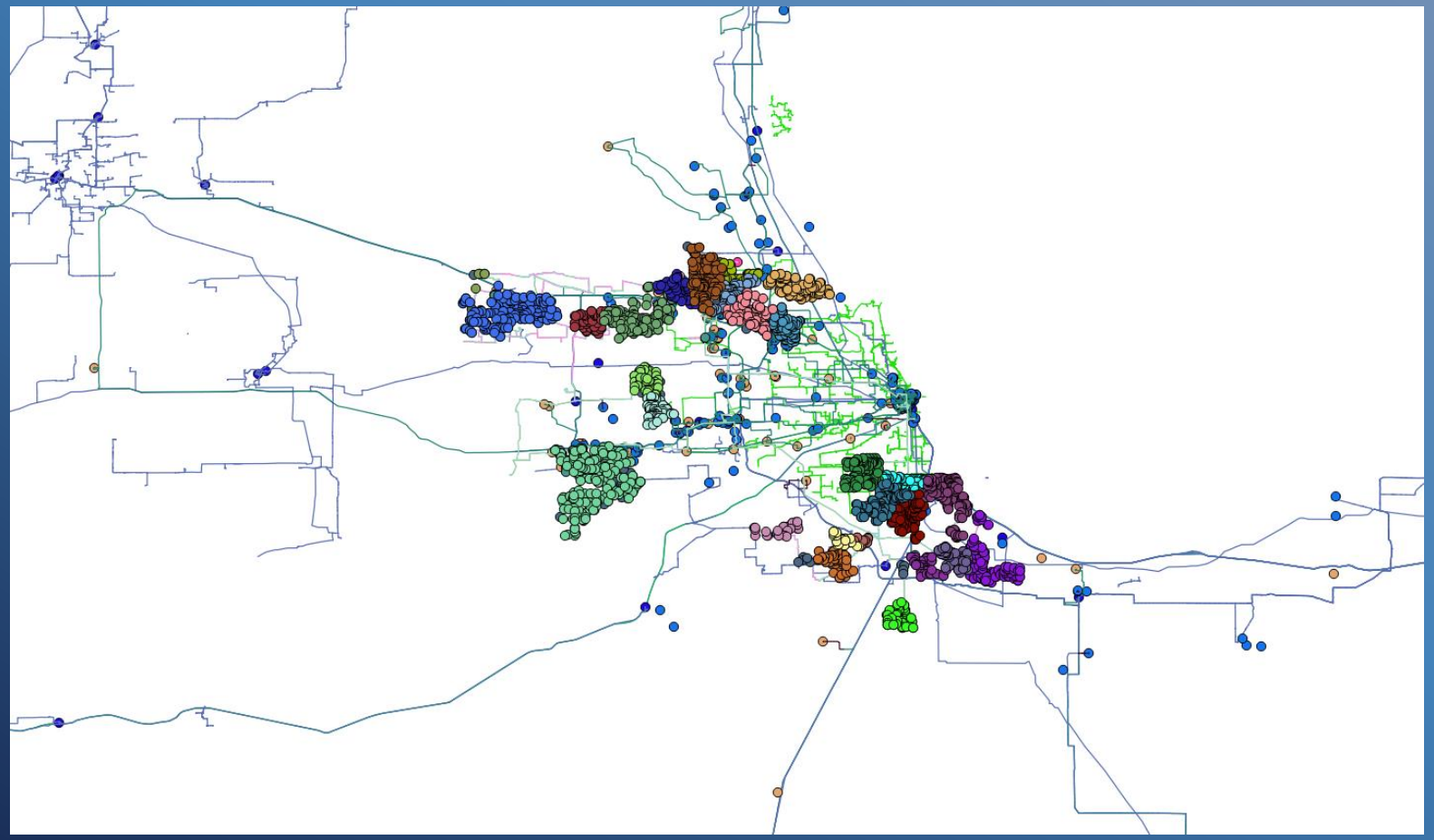
Provider 3: Wide Open West (WOW) Fiber Network



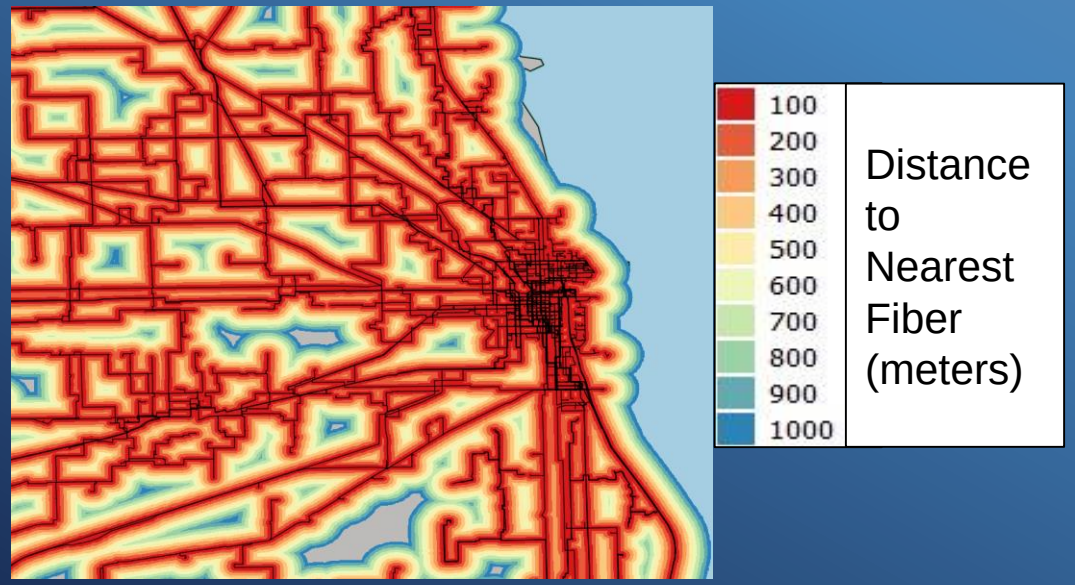
Provider 4: Zayo Fiber Network

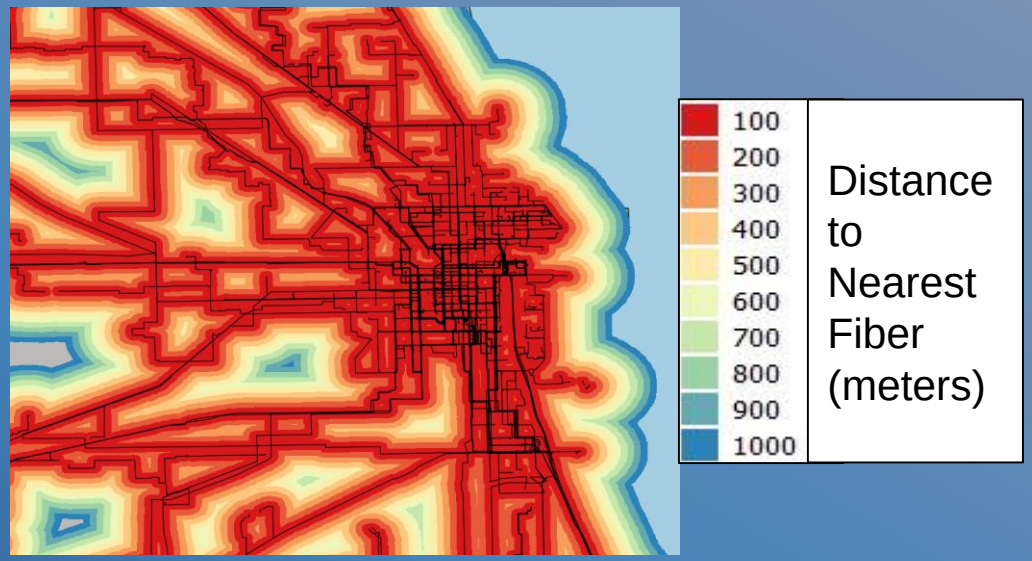


Chicagoland lines and nodes



Chicago (Urban Core) Proximity Heat Map





Enlarged views of Proximity Heat Map (Core of Urban Chicago)